COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

McGRAW-HILL PUBLICATIONS IN THE
AGRICULTURAL SCIENCES
R. A. BRINK, *Consulting Editor*

ADRIANCE AND BRISON · Propagation of Horticultural Plants
AHLGREN · Forage Crops
ANDERSON · Diseases of Fruit Crops
BROWN AND WARE · Cotton
CARROLL, KRIDER AND ANDREWS · Swine Production
CHRISTOPHER · Introductory Horticulture
CRAFTS AND ROBBINS · Weed Control
CRUESS · Commercial Fruit and Vegetable Products
DICKSON · Diseases of Field Crops
ECKLES, COMBS, AND MACY · Milk and Milk Products
ELLIOTT · Plant Breeding and Cytogenetics
FERNALD AND SHEPARD · Applied Entomology
GARDNER, BRADFORD, AND HOOKER · The Fundamentals of Fruit Production
GUSTAFSON · Conservation of the Soil
GUSTAFSON · Soils and Soil Management
HAYES, IMMER, AND SMITH · Methods of Plant Breeding
HERRINGTON · Milk and Milk Processing
JENNY · Factors of Soil Formation
JULL · Poultry Husbandry
KOHNKE AND BERTRAND · Soil Conservation
LAURIE AND RIES · Floriculture
LEACH · Insect Transmission of Plant Diseases
MAYNARD AND LOOSLI · Animal Nutrition
METCALF, FLINT, AND METCALF · Destructive and Useful Insects
NEVENS · Principles of Milk Production
PATERSON · Statistical Technique in Agricultural Research
PETERS AND GRUMMER · Livestock Production
RATHER AND HARRISON · Field Crops
RICE, ANDREWS, WARWICK, AND LEGATES · Breeding and Improvement of
Animals
ROADHOUSE AND HENDERSON · The Market-milk Industry
STEINHAUS · Principles of Insect Pathology
THOMPSON · Soils and Soil Fertility
THOMPSON AND KELLY · Vegetable Crops
THORNE · Principles of Nematology
TRACY, ARMERDING, AND HANNAH · Dairy Plant Management
WALKER · Diseases of Vegetable Crops
WALKER · Plant Pathology
WILSON · Grain Crops
WOLFE AND KIPPS · Production of Field Crops

The late Leon J. Cole was Consulting Editor of this series from 1937 to 1948.
There are also the related series of McGraw-Hill Publications in the Botani
ences, of which Edmund W. Sinnott is Consulting Editor, and in the Zo
Sciences, of which Edgar J. Boell is Consulting Editor. Titles in the Agri
Sciences were published in these series in the period 1917 to 1937.

A Textbook for Student, Investigator, and Manufacturer

Commercial Fruit and Vegetable Products

1958

W. V. CRUESS

Professor Emeritus of Food Technology
and Chemist in the Experiment Station
University of California at Berkeley

FOURTH EDITION

McGRAW-HILL BOOK COMPANY, INC.

New York Toronto London

1958

COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

 Library of Congress Catalog Card Number 57–12894

5 6 7 8 9 – MP – 9 8 7 6

14808

PREFACE

This book has been prepared primarily to serve students in horticulture, food chemistry, and horticultural products. Therefore the application of the fundamental sciences to the manufacturing and preserving processes concerned is given prominence equal to that of the strictly practical phases. The book is based upon lectures given by the author to students in fruit and vegetable products during many years, and the subject matter is developed from the viewpoint of the instructor rather than from that of the manufacturer.

Nevertheless, it is believed that commercial canners and others engaged in the fruit and vegetable products industries will find most of the information given about their respective industries to be of direct value in the operation and control of their plants. In addition to serving as a reference book for the factory manager, superintendent, or chemist, the book will be of value to the foremen and other employees in the organization who desire to increase their technical knowledge of the industry.

In order that this book might not cover too wide a field, attention has been centered principally upon those industries more directly affecting the fruit and vegetable grower rather than the producers of field crops and of livestock.

Since the first publication of this book in 1924, improvements in equipment and processing have called for its revision, first in 1938 and again in 1948. Since publication of the third edition in 1948, further important advances have been made in food processing and preservation. This is particularly true in the freezing of fruits and vegetables, the technology of canning, and the production of fruit concentrates. Likewise, much productive research has been done in the basic sciences upon which food technology depends.

Therefore it has become necessary to revise and expand certain chapters extensively. In order that the total number of pages should not exceed the practicable limit for a single volume, it has been necessary to curtail the discussion of several subjects. However, much of the more important information on such topics has been retained. This is particularly true of the subjects vitamin retention, historical notes, packages and packaging, plant pigments, the role of enzymes, and microorganisms in relation to

processing and preservation. Since wine making is of limited interest to canners, freezers, and most other prospective users of this book, and since several comprehensive books and university bulletins are available on this subject, this topic, former Chapter 30, has been omitted. Similar considerations apply to former Chapter 26, olive and coconut oils, which also has been dropped.

The author feels that these omissions are more than offset by the new information presented in the chapters on canning, freezing, drying, spoilage, and other subjects.

The author wishes to repeat the acknowledgment of his gratitude to Professor A. W. Christie and others as expressed on page viii of the first edition and to those persons and organizations listed on pages viii and ix of the third edition. In addition, he wishes to express his appreciation to the following for new information and for assisting in other ways: Walter Mercer, F. G. Lamb, and Norman Olson of the National Canners' Association; G. W. Cole of the Exchange Lemon Products Company; Jesse W. Stevens of the Exchange Orange Products Company; R. Sutherland of the F. W. Bireley Company; R. Webster and H. Schutt of Lindsay Ripe Olive Company; R. Ball and J. Jaquith of Pacific Olive Company; Ernest Develter of Feather River Olive Association; John Patten of Western California Canners, Inc.; Maywood Packing Company; E. E. Jaffe of the Puccinelli Canning and Dehydrating Company; R. Quirk and Geo. E. Felton of Dole Hawaiian Pineapple Company; the Magnuson Engineering Company of San Jose, California; Dr. H. Griswold and C. L. Smith of Owens Illinois Glass Company; S. Leonard and B. S. Luh of the author's department of the University of California; Professor Matthew Highlands of Maine College of Agriculture; C. D. Buss of Flotill Products, Inc.; the many California canners, freezers, dried-fruit packers, preservers, and other industrial producers who furnished valuable technological information, and the canners, freezers, and other industrial processors in eastern Oregon and Washington and in the Salem-Eugene area in Oregon for valuable information obtained on visits by the author during the 1955 season. Thanks are due also to the manufacturers of food-processing equipment and laboratory instruments for technological data and for photographs used in illustration. Specific acknowledgment is made in the legends of the various illustrations.

W. V. Cruess

CONTENTS

CHAPTER 1

GENERAL PRINCIPLES AND METHODS

A brief discussion of the more important principles and processes underlying the manufacture and preservation of fruit and vegetable products should precede the description of methods of applying these principles industrially.

TEMPORARY PRESERVATION

Some of the most important of the food industries are based upon methods of temporary preservation. The method to be chosen will vary with the product to be held temporarily and with other factors.

Asepsis. The inception of spoiling of a food product depends largely upon the numbers of microorganisms present. In the handling of fruit for the manufacture of various fruit products, care in picking, placing in boxes, and transportation will greatly increase the keeping qualities of the fruit and will usually result in a finished product of superior quality. Dirty lug boxes and rough handling infect and bruise the fruit so that microorganisms are greatly increased in numbers and conditions are made favorable for their growth.

Washing dusty fruit and vegetables before they are used in the manufacture of certain products is often advisable and reduces the number of microorganisms.

Certified milk is made under conditions that tend to exclude most microorganisms from the milk. Its production is a good example of industrial asepsis.

The principle of asepsis is carried to a much higher degree in the manufacture of serums, vaccines, and antitoxins. In these cases the absolute exclusion of microorganisms is sometimes accomplished. This is also true in the preservation of fruit juices by germproof filtration.

Low Temperatures. Microorganisms are not killed by low temperatures, but their multiplication and activities are inhibited. Low temperatures also retard chemical changes.

Enormous quantities of eggs, meats, fruits, and vegetables are held in cold storage so that they may be made available for a larger proportion of

the year. In all cases the principle involved is the same, viz., the temporary inhibition, by low temperatures, of microbiological and chemical action responsible for decomposition.

Exclusion of Moisture. Moisture is necessary for the development of microorganisms, and the actual growth of mold and other organisms on or in food products takes place in the juice of the product. If the concentration of dissolved solids in this juice or sap exceeds 70 per cent, i.e., if the osmotic pressure exerted by the solution is equal to or greater than that exerted by a 70 per cent sugar solution, the product will usually keep. If moisture collects on the surface of the dried or other product, it forms a solution lower in dissolved solids than is necessary to prevent growth. It is in this dilute solution that growth often takes place.

FIG. 1. Pilot plant of University of California, Food Technology Department, Davis, Calif.

Chemical changes in flour, cereals, dehydrated vegetables, oils, etc., are favored by the presence of moisture; hence these products should be stored in a dry atmosphere.

Mild Antiseptics. Preservatives such as sugar, salt, sodium benzoate, SO_2, etc., when used in small quantities, exert only a temporary effect upon the microorganisms of spoilage. Cider often is treated with small amounts of sodium benzoate to preserve it temporarily. Vinegar and spices in catsup will prevent spoilage for a time, usually for several weeks after the bottle is opened.

Pasteurization. When a product is subjected to a temperature that kills a great many, but not all, of the organisms present, the process is spoken of "pasteurization."

The heating not only kills many organisms but also greatly weakens and delays the development of those not killed, which is an important factor in the keeping of pasteurized products.

The term "pasteurization" is often applied to the preservation of fruit

juices by heat. In this case, however, it is very probable that all organisms capable of growing in the liquid are destroyed by the heat, and hence preservation is usually permanent.

Exclusion of Air. The exclusion of air will often prolong the keeping qualities of fruit products. For example, olive oil becomes rancid on exposure to air but will keep several years if air is effectively excluded. Most fermented products, such as wine, fermented vegetables, and green-olive pickles, must be sealed in airtight containers to prevent the growth of aerobic organisms which would spoil them.

Electromagnetic Radiation. A great deal of research is under way at present on the sterilization of food products with various forms of electromagnetic radiation. See Chapter 7.

PERMANENT PREVENTION OF SPOILING

The permanent preservation of food may be accomplished in several ways, most of which depend upon methods of completely eliminating or preventing the activity of microorganisms capable of destroying the product. The method to be adopted will depend upon the character of the material to be preserved and upon other factors.

Sterilization or Processing by Heat. Sterilization by heat means the complete destruction by heat of all forms of life in the product sterilized. In order that sterilized products shall not spoil, they must be sealed in such a manner that all live microorganisms are excluded.

In commercial practice not all cans of food are sterile. Nevertheless, they usually do not spoil because conditions in the can are not favorable for the organism concerned. The pH may be too low, or oxygen may be lacking. Therefore the term "processing" is preferable to the term "sterilization" when applied to canned foods.

The temperature necessary to sterilize different products varies. The products that are difficult to sterilize are low in acid and often high in protein and contain spore-bearing bacteria. The acidity of fruits, tomatoes, and rhubarb greatly lowers the death or sterilizing temperatures of the organisms occurring on these products, which explains why acid fruits are easily sterilized, even if spore-bearing organisms are present.

The effect of hydrogen-ion concentration (acidity) is more fully discussed in Chapter 7.

Sterilization or Processing below 100°C. (212°F.). Fruit juices are usually processed commercially at temperatures ranging from 65 to 85°C. Higher temperatures injure the flavor. This is done in one of two ways, viz., by heating in the sealed container or by flash pasteurization, filling hot, and sealing.

One Heating at 100°C. (212°F.). Fruits are easily preserved at 212°F.,

and heating at this temperature is usually for the purpose of cooking the fruit rather than for sterilizing it.

Vegetables, except those of high acidity, when sterilized by one heating, must be heated at 100°C. (212°F.) for many hours to be certain that all spores are killed.

As a general rule, the one-period sterilization of meats and vegetables at 100°C. (212°F.) is unsafe because of danger of survival of spores of *Bacillus botulinus*, i.e., *Clostridium botulinum.*

Intermittent Processing at 100°C. The action of heat is usually rendered more effective if the time of sterilization is divided into three periods, three sterilizations of 1 hr. each at 100°C. being much more effective than a single sterilization at 100°C. The sterilizations are generally separated by periods of 24 hr. This method is much safer than the one-heating method at 100°C. for vegetables of low acidity. However, it has been proved that this method does not destroy the spores of *B. botulinus* in nonacid foods.

Effect of Acidification. Vegetables and meats acidified with lemon juice or vinegar are easily sterilized. This principle is made use of in the so-called "lemon juice" method first advocated by the author in 1916 in *University of California Agricultural Experiment Station Circular* 158. In this method a small amount of lemon juice, vinegar, citric acid, or other harmless acid is added to the brine in which the vegetables are canned, so that after sterilization the pH will be below 4.5 (see also Chapter 7).

Use of Steam under Pressure. The boiling point of water is raised if the water and steam are enclosed in a strong retort (autoclave). A temperature of 116.6°C. (250°F.) or above may be easily attained, and at these high temperatures the spores of the heat-resistant bacteria are quickly killed.

Tomato juice is often preserved by heating to about 250°F. in a continuous flash sterilizer, cooling continuously to about 210°F., and canning hot. In the Martin aseptic canning process, liquid nonacid products are flash-heated to a very high temperature, cooled to room temperature in a sterile, closed system, and filled aseptically into sterile cans (Chapter 7).

Permanent Preservation by Antiseptics. Foods may be preserved permanently by the addition of antiseptics in sufficient concentration to prevent the growth of microorganisms. Some antiseptics, such as sugar, salt, and vinegar, are harmless and may be used without reference to the pure-food laws. Many chemical preservatives, such as salicylic acid, formaldehyde, boric acid, etc., are harmful to health, if used in sufficient quantity to preserve the food product permanently, and are prohibited by law.

Sugar used in concentrations of 70 per cent or over will permanently preserve most foods like fruit jellies, preserves, etc. It acts by osmosis and not as a true microorganism poison.

Salt acts both by osmosis and as a microorganism poison; hence it is much more effective than sugar. About 15 per cent salt is sufficient to preserve most products. *Acetic acid* of vinegar acts as a microorganism

poison and is much more active in this regard than salt. About 2 per cent of acetic acid will prevent the spoiling of most products.

Chemical preservatives are still more active. Two-tenths per cent of sodium benzoate will prevent the spoiling of most acid food products. The amount required varies with the pH value. Thus Richert, Irish, and the author found that below pH 4.5, 0.2 per cent preserved food products, and at neutrality, pH 7.0, 1 per cent was insufficient. Sulfurous acid may often act as a permanent preservative for fruit products when used at a concentration in excess of 0.2 per cent. Benzoic acid and sulfurous acid are allowed by law if declared on the label. Other chemical preservatives in foods are prohibited in the United States.

Drying. Preservation by drying depends upon reducing the moisture content to the point at which the concentration of the dissolved solids in the product is so high, 70 per cent or above, that osmotic pressure will prevent the growth of microorganisms.

The amount of drying necessary will depend largely upon the composition of the food. Thus fruits very rich in sugar are not usually dried to as low a moisture content as fruits low in sugar.

The various methods of accomplishing drying will be fully discussed in a later chapter.

Preservation by Fermentation. Microorganisms may be used for the preservation of foods as well as for their decomposition. *Fermentation* may be defined as the decomposition of carbohydrates by microorganisms or enzymes, as contrasted with *putrefaction*, which may be defined as the bacterial decomposition of proteins.

Alcoholic Fermentation. Alcoholic fermentation by yeast results in the decomposition of the simple hexose sugars into alcohol and carbon dioxide, as indicated by the following reaction:

$$C_6H_{12}O_6 + \text{yeast} = 2C_2H_5OH + 2CO_2$$

The keeping quality of alcoholic beverages depends upon the presence of the alcohol. Usually air must be excluded from products fermented by yeast in order to prevent the activities of aerobic organisms, such as vinegar bacteria, molds, and film yeasts.

Acetic Fermentation. Vinegar fermentation follows normal alcoholic fermentation and is brought about by vinegar bacteria. The keeping quality of vinegar is entirely due to the antiseptic action of the acetic acid. The most important use for the preservative action of the acetic acid is for the preservation of various food products like pickles, relishes, catsup, etc. The reaction involved in acetic fermentation is

$$C_2H_5OH + O_2 = CH_3CO_2H + H_2O$$

Lactic Fermentation. Lactic acid fermentation is used very extensively in the preservation of sauerkraut, dill pickles, fermented string beans, ensilage,

and green olives. Materials that have undergone lactic acid fermentation must be kept sealed from the air to prevent the growth of acid-destroying aerobes; hence the necessity of making silos airtight and of sealing sauerkraut and similar lactic acid fermented products from the air. Lactic acid fermentation is a decomposition of the hexose sugar molecule, as indicated by the following reaction:

$$\underset{\text{Dextrose}}{C_6H_{12}O_6} = \underset{\text{Lactic acid}}{2C_3H_6O_3}$$

The usual yield of lactic acid is about 90 per cent of the theoretical. Acetic fermentation and lactic fermentation are discussed in Chapters 21 and 22.

Exclusion of Air. Some food products, such as nut meats and salad oils, are spoiled by the simple oxidizing action of the oxygen of the air; others by the action of microorganisms that require air for their development. Fermented products must be sealed from the air in some manner if the action of mold, vinegar bacteria, film yeasts, and other organisms is to be prevented. This is especially true of fermented vegetables.

MANUFACTURING PROCESSES

Many of the industrial processes by which fruits and vegetables are converted into more valuable products are not those of simple food preservation but are highly developed manufacturing processes. The principles of the more important of these are outlined below.

Separation of Valuable Materials from Less Valuable Materials. A large number of processes are based upon this principle. Of these the more important are the following:

Crushing and Pressing. Crushing and pressing of fruits, sorghum, and sugar cane result in the separation of the valuable juices and saps from the less valuable pulp and fiber.

Filtration. Many liquids, such as fruit juices, wines, vinegars, vegetable oils, etc., contain solid material that must be removed by filtration. In most cases the liquid is the valuable portion, but in some instances the main value lies in the solid residue. Thus in the manufacture of citric acid, the calcium citrate is a valuable solid and is separated from the lemon juice by filtration.

The simplest filter is the jelly bag of the type used by the housewife in preparing fruit juices for jelly. Paper filters are used for the filtration of olive oil in many factories. Filter presses employing cloth or other filtering medium, wood-pulp filters, and filters employing asbestos fiber are used. These will be described in Chapter 12. Often a filter aid such as diatomaceous earth is added to the liquid to be filtered.

Flotation. Materials that are mixed and of different specific gravities may be separated by placing them in a liquid in which one will sink and the other will float. After the pits have been crushed, apricot hulls and kernels are separated in this way. In a similar manner frozen oranges are separated from the sound fruit in running water. Overmature peas are separated from the green for canning, and Lima beans for ripeness for freezing, by use of brines.

Leaching. Sugar, alcohol, and other soluble materials may be separated from fruit pomace, etc., by treatment with water, and oils may be recovered from oil-bearing material, such as olive pomace, by the use of an oil solvent.

Diffusion. This is a method similar to the preceding and is used mostly in beet-sugar manufacture. The sliced beets are surrounded by warm water in a series of tanks known as a "diffusion battery." The sugar diffuses through the cell walls of the sliced beets into the surrounding water, and this solution is drawn off and concentrated. The same principle may be applied to other vegetables and fruits. It depends upon osmosis, i.e., the tendency of liquids outside and inside the cell to come to the same concentration.

Distillation. Volatile compounds can be separated from less volatile ones by distillation. Alcohol is separated from water and from other less valuable materials, and in this manner essential oils are recovered from the flowers, herbs, or fruits in which they occur.

Types of stills vary greatly in size and design. Most commercial stills for alcohol contain rectifying columns, through which the vapors pass; the columns are maintained at such temperature that the constituents are condensed at different points and separated.

All stills not only vaporize one or more constituents but also condense the vapors to liquids again; i.e., they consist at least of a still in which the materials are vaporized and a condenser in which the vapors are condensed. By the simple distillation of a fermented fruit juice, it is possible to obtain, by a single distillation, a distillate containing about 60 per cent alcohol; by the use of a rectifying column, it is possible to obtain 94 per cent alcohol by a single distillation.

Some products may be distilled by the direct application of heat to the still; others can be distilled only if a current of steam is passed through the material, as in recovering bitter-almond oil from almonds or apricot kernels.

Distillation is the most important process in the manufacture of alcohol, acetic acid, acetone, and most essential oils.

Centrifugal Separation. The tendency of certain materials to separate by the action of gravity is enormously increased by the application of centrifugal force, which is obtained by whirling.

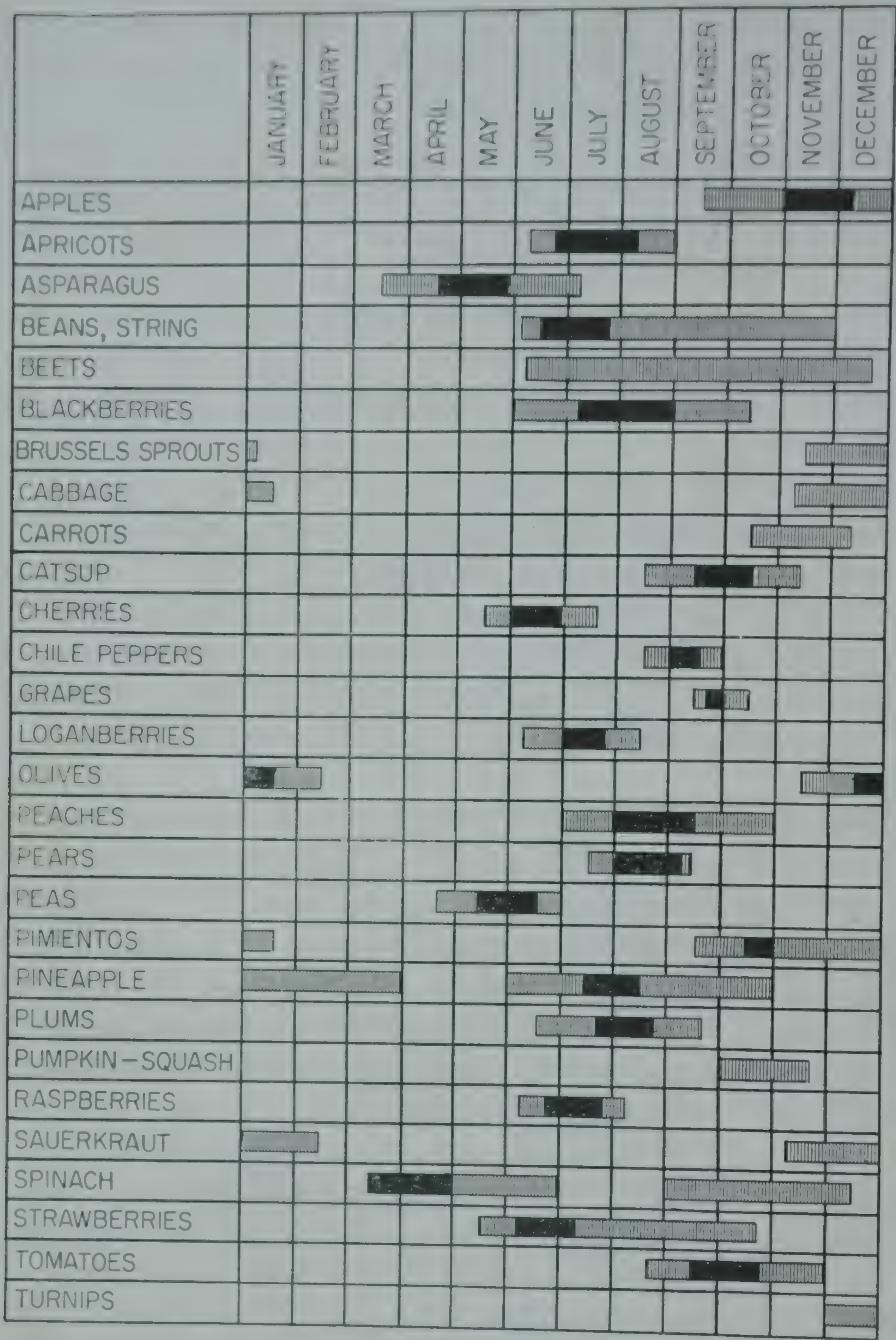


FIG. 2. Chart showing fruit and vegetable canning seasons in California and pineapple season in Hawaii. Heavy black lines represent periods of maximum activity. (*California Packing Corp.*)

Centrifugal force depends principally upon the rate of spinning of the centrifuge but is also dependent to a less degree on its diameter. Some centrifuges can be operated at 40,000 revolutions per minute (r.p.m.) and increase the pull of gravity several thousand times. Thus materials that require days for settling naturally will separate almost instantly under powerful centrifugal action.

Some centrifuges are continuous. Other forms are not continuous and

must be charged before whirling and cleaned after the operation is completed. Centrifugal force is used in the clarification of fruit juices, the separation of oils from water and fruit juice, and the separation of crystals from mother liquors.

Crystallization. Cream of tartar and certain organic acids, sugars, etc., are recovered commercially by the application of the principle of crystallization. Crystallization depends upon concentration of the solution to such a point that it becomes supersaturated. The solute then separates slowly as very small crystals. As the concentration proceeds, these crystals grow in size. They usually separate as pure compounds; however, a certain amount of the mother liquor or solution usually clings to the crystals, and then they must be redissolved and recrystallized.

Sifting. Mechanical sifting is used to separate coarse from fine materials. It is of most use in threshing various cereals but also may be used in separating grape seeds from the skins and stems and has other uses in the horticultural industries.

Size Classification. Certain fruits and vegetables are separated into several sizes by means of suitable screens, diverging cables, or other equipment (Chapter 4).

Conversion of Raw Materials into New Products. Many raw products must be transformed into new products by processes some of which are chemical in nature and others mechanical.

Fermentation. Fermentation, one of the most important processes used in the manufacture of valuable products from raw material, may be conducted by any one of three main groups of microorganisms, i.e., by yeasts, molds, or bacteria. The products of fermentation of most importance are alcohol, acetic acid, lactic acid, butyl alcohol, critic acid, and acetone.

Alcoholic Fermentation. Alcoholic fermentation is essential in the manufacture of denatured alcohol and vinegar and all fermented beverages (see also Chapter 21).

Pure Cultures. The most important means of control of alcoholic fermentation is the addition of a starter of the desirable type of yeast. Industrial pure culture methods and other factors will be described in Chapter 21.

Other Fermentations. Other fermentations are controlled by methods similar to those used in the control of yeast fermentation. The details of these methods will be discussed in later chapters dealing with the commercial application of these fermentations. The most important of these fermentations are vinegar fermentation, lactic acid fermentation, butyl fermentation, citric fermentation, and the various starch-hydrolysis "fermentations" caused by starch-splitting molds.

Hydrolysis. The hydrolysis of starch by the use of enzymes or by acids to maltose or dextrose (glucose) is one of the most important hydrolyzing reactions used industrially. Malt from barley is most commonly used for

the hydrolysis of starch to maltose, and acids are generally used in the manufacture of glucose from starch.

The manufacture of bitter-almond oil from apricot, peach, and almond pits depends upon hydrolysis of amygdalin by emulsin, an enzyme occurring in the kernels. Apple juice is usually clarified by a pectin-splitting enzyme added for this purpose.

Other Processes. Vegetable oils are refined by treatment with various chemicals, and objectionable flavors and odors are removed with a current of air or by steam.

A very important industry, more or less allied to the horticultural industries, is wood distillation followed in the preparation of charcoal. This process is carried out at temperatures that cause the wood to decompose with the formation of wood alcohol, acetone, acetic acid, water, and tar, which last contains valuable by-products. Charcoal remains in the retort. At some future period it may be profitable to utilize fruit hulls, pits, and prunings from orchards and vineyards in this way.

Considerable amounts of apricot and peach pits are converted into charcoal briquettes for use in steak broilers.

Some organic acids such as citric and tartaric are recovered from fruit juices by precipitation as insoluble calcium salts.

Unit Processes and Unit Operations. Brown and associates (1950) and Burton (1940) have stressed the advantages of considering food processing and other industrial procedures according to the unit-operations concept. A unit operation is usually considered as a step in processing or manufacturing that is incapable of division into smaller units. An example in the canning of peaches is elevating the fresh fruit by conveyer to the lye-peeling machine.

A unit process includes several unit operations. An example is the lye peeling of clingstone peaches for canning, a process that includes at least four unit operations. In brief, a unit process in food technology involves transformation of the product being processed. Thus in the lye peeling of peaches the halved fruit is transformed into the peeled product.

This viewpoint permits focusing of the attention on a single step, or single piece of equipment, or a single procedure, any one of which may be applied in producing several or many different items. Filtration, for example, is used in the making of juices, vegetable oils, wines, sirups, vinegars, aged brandies, and other products.

Unit Processes. The preparation and recovery of calcium citrate from lemon juice is a good example of a unit process involving several unit operations. The juice is first fermented in order to facilitate settling and filtration; it is then filtered; a slurry of lime in water is prepared; the juice is measured by volume or weighed; a predetermined volume or weight of the lime slurry is added; the mixture is heated in order to hasten the reac-

tion and to render the citrate insoluble; the mixture is filtered; the solid citrate is removed from the filter and is then dried.

Other common processes of the food industries are the following: lye peeling of fruits and vegetables, mechanical pitting of fruits, pickling of ripe olives, pickling of vegetables and green olives, dehydration of fruits and vegetables, freezing preservation, making of jellies, clarification of juices, wine, and vinegars with bentonite clay or other fining agent, concentration of fruit juices or berry preserves under vacuum, canning of fruits and vegetables, making jams and preserves, and the blanching of fruits and vegetables for canning, drying, and freezing. Many others are discussed in later chapters.

Unit Operations. As previously noted, a unit operation is one that cannot be subdivided into simpler units. However, this definition is not always closely adhered to. For example, centrifuging is usually listed as a unit operation; but in the centrifuging of crude citric acid crystals several separate steps are involved; e.g., the basket is set spinning by the driving motor, the crude acid is loaded into the spinning basket, the crystals are sprayed with a fine spray of water to wash off the adhering mother liquor, and the washed crystals are dumped from the basket for subsequent drying. Consequently, in this case, centrifuging might be considered a unit process. The point that we wish to make is that authors do not always agree in detail on what constitutes a unit operation or unit process under any and all conditions.

Burton (1940) classifies unit operations in the food industries into 11 categories, viz., separating, materials handling, heat exchanging, mixing, disintegrating, forming, controlling, packaging, storing, coating, and decorating.

Typical unit operations, most of which in the following list are from Burton (1940) include draining, evacuating, pitting, deaeration, screening, sorting, sifting, riffling, trimming, moving air by fan, inspecting, measuring, weighing, temperature control, humidity control, capping, closing, crimping, double seaming of cans, filling, labeling, packing, wrapping, stacking, piling, dipping, enrobing, glazing, icing, tabling, cleaning, washing, and conveying. Many other examples might be given.

Processing versus Engineering. In the processing and preservation of food products the plant chemist, quality-control man, or the superintendent usually has a very clear and comprehensive knowledge of the properties of the raw material and of the finished product; i.e., he knows what must be done with the raw material to convert it into the finished product, but may not have, as Burton points out, the proper training and experience in engineering to design or select the most efficient and satisfactory equipment for each operation or process or to install it so that its operation will be efficient and synchronize with other units in the line.

In a large establishment these functions are often best delegated to the plant's engineering staff; in small plants to the engineering staff of the company that is supplying and installing the equipment. In other words, very often engineering training and experience are of great value in food processing and preservation. In addition to knowing what is to be done, the engineer must also know or "find out" how to do it on a commercial scale at a profit. The unit-operation and unit-process concept is of great value in attaining this objective.

Antibiotics in Canning. Late in 1949 bacteriologists of the Western Regional Research Laboratory of the U.S.D.A. reported that an antibiotic, subtilin, used in conjunction with mild heating greatly lowered the temperature required to prevent spoilage of nonacid canned vegetables inoculated with heat-resistant spores of certain canned-food spoilage organisms. Antibiotics are widely used in the treatment of many different bacterial diseases of man and domestic animals. They have the peculiar and extremely important property of inhibiting the growth of or actually destroying many microorganisms. Several of the better-known antibiotics are penicillin, streptomycin, aureomycin, and subtilin. They are produced by certain microorganisms.

As a result of the U.S.D.A. findings, the research laboratories of the National Canners Association, American Can Company, and the Continental Can Company have conducted a very extensive investigation on this subject. The following quotation is from a report of the National Canners Association made in 1950.

> The general indications were that whenever the products are inoculated with putrefactive anaerobes or *Cl. botulinum* and a lower order of process such as 35 minutes at 212°F, $F_o = 0.1$ is used, even though concentrations of subtilin as high as 80 ppm. or spore concentrations as low as 1,000 per can are used, sterility did not always ensue. Also, whenever spoilage with *Cl. botulinum* developed, toxin was invariably produced. Where subtilin was used without deliberate inoculation, spoilage was absent or markedly reduced. Also, flat sour spoilage was retarded for 90 days in both peas and corn, even though inoculations of the order of 240,000 spores per can were employed and processes were as low as 35 minutes at 212°F.

In a later National Canners Association report (1953), the following statement appears.

> The Food and Drug Administration, on Feb. 25, 1953, published an announcement that the use of antibiotics in food for human consumption constitutes a public health hazard. As a result, the program of testing various antibiotic substances submitted by pharmaceutical companies was brought to a close. The action of 17 of these antibiotics was determined using *Clostridium botulinum*, Types A and B. Only one of these substances (Merck's numbered antibiotic 52–R4–400) showed any exceptional activity. However, its action on *Cl. botulinum* was principally inhibitory and inhibition gradually dissipated on long storage (six months).

Morse in 1950 gave a useful résumé of this subject. Evidently, certain canned-food spoilage organisms are markedly affected by certain antibiotics, but the putrefactive anaerobes, notably *Cl. botulinum*, are merely temporarily inhibited. Another objection to the use of antibiotics in canning is that residual antibiotics in the canned food might affect the consumer adversely. Also, their continued use might result in the development of resistant strains of spoilage bacteria, as appears to have occurred with certain disease bacteria. At any rate, antibiotics are not being used in the canning of foods at present, and prospects for their use in this manner in the future are not good.

REFERENCES

BROWN, G. G., and ASSOCIATES: "Unit Operations," John Wiley & Sons, Inc., New York, 1950.

BURTON, L. V.: Engineering a food manufacturing process [unit operations], *Proc. Inst. Food Technologists*, June, 1940, pp. 1–11.

CRUESS, W. V., RICHERT, P. H., and IRISH, J. H.: Effect of hydrogen ion concentration on the toxicity of preservatives to microorganisms, *Hilgardia*, **6**(10), 1930.

DUNN, C. G., CAMPBELL, W. L., FRAM, H., and HUTCHINS, A.: Biological and photochemical effects of high-energy, electrostatically produced roentgen and cathode rays, *J. Applied Phys.*, **19**, 605–616, 1948.

JACKSON, W. D., POMERANTZ, R., EVANS, B., and MORGAN, B. H.: Radiation sterilization of foods, Q.M. Food and Container Institute, Chicago, 1955.

JONES, O., and JONES, T. W.: "Canning Practice and Control," Chemical Publishing Company, Inc., New York, 1937.

KINN, T. P.: Basic theory and limitations of radio high frequency heating equipment, *Food Technol.* **1**, 161–173, 1947.

MARTIN, C. O., BROWN, L. H., HAZELTON, S. H., JR., NOBLE, K. M., PRUSSIA, R. S., THALLON, R., and WILDER, H. K. (Committee of Lighting in Canneries): Lighting for canneries, *Illum. Eng.*, January, 1950.

MOLINARI, E.: "Industrial Organic Chemistry," The Blakiston Division, McGraw-Hill Book Company, Inc., New York, 1921.

MORRIS, T. N.: "Principles of Fruit Preservation," Chapman & Hall, Ltd., London, 1933.

MORSE, R. E.: Canning with antibiotics, pro and con, *Food Inds.*, **22**(10), 40–42, 1950.

National Canners Association Research Laboratories: Annual Report, 1950, pp. 11–13; 1953, pp. 9–11. Use of antibiotics in canning.

NICKERSON, J. T. R., PROCTOR, B. E., and GOLDBLITH, S. A.: Ionizing radiations in the processing of plant and animal products, *Food Technol.*, **10**(7), 305–312, July, 1956.

PRESCOTT, S. C., and PROCTOR, B. E.: "Food Technology," McGraw-Hill Book Company, Inc., New York, 1937.

PROCTOR, B. E., and GOLDBLITH, S. A.: Electromagnetic radiation fundamentals and their application in food technology, pp. 119–196, in E. M. MRAK and G. F. STEWART, "Advances in Food Research," vol. 3, Academic Press, Inc., New York, 1951.

Radiation sterilization of foods, *Spec. Rept., Western Canner and Packer*, 1955.

SADTLER, S. P., and MATOS, L. J.: "Industrial Organic Chemistry," 5th. ed., J. B. Lippincott Company, Philadelphia, 1922.

WALKER, W. H., LEWIS, W. K., McADAMS, W. H., and E. R. GILLILAND: "Principles of Chemical Engineering," McGraw-Hill Book Company, Inc., New York, 1923.

CHAPTER 2

TIN AND GLASS CONTAINERS[1]

While Appert used glass containers principally in his experiments and in his "cannery," the tin container during the past hundred years has largely displaced the glass container in the commercial "canning" of foods. On the other hand, glass is the usual container for commercially produced jams, jellies, preserves, green olives, and various kinds of pickles. In the household the glass container is used to the practical exclusion of the tin for home preservation of fruits, vegetables, meats, preserves, etc. It is also the commercial container for fresh milk, powdered coffee, catsup, and wines, and large quantities of glass bottles are used for fruit juices and beer. At present each container is invading the other's fields; thus, much beer is now preserved in cans, and glass jars that will withstand processing in an agitating sterilizer are now being successfully used for "canned" fruits. Cans, for the time being, have replaced glass containers for pasteurized pineapple, grapefruit, and orange juices, and the glass jar is now competing with the tin can as a container for vacuum-packed coffee. It is estimated that more than three billion cans are used as containers for foods annually. Probably an even greater number of glass containers are used if one includes those used commercially for milk and beer and in home food preservation. Plastic film and cardboard are used for packages for dried and for frozen foods (Chapters 20 and 25).

TIN CONTAINERS

Tin-coated vessels have been known since ancient times. They were mentioned by Pliny prior to A.D. 23, according to Macnaughton and

[1] Much of the information presented in this chapter on glass and glass containers was kindly furnished by Dr. Hugh Griswold and C. L. Smith of the research staff of the Owens Illinois Glass Co. The author desires to express his sincere thanks and appreciation to them. Thanks are also due the Pitman Publishing Co. of New York and Chicago for permission to use some information from Phillips' book on glass (see reference list). The author wishes to express his appreciation also to the American Iron and Steel Institute, the Tin Research Institute, R. B. Meneilly, R. R. Hartwell, R. W. Pilcher, Roger Lueck, K. W. Brighton, E. D. Martin, A. E. Stevenson, and W. E. Hoare for valuable information on tin plate and tin containers. For additional information see references at the end of this chapter.

Hedges. They relate that according to legend a Cornish tin miner migrated to south Germany in medieval times, and there discovered tin in the Erzgebirge about 1240. The date of the discovery of the process of making tin plate, they state, must have been between 1240 and 1575, since tin was being exported to Germany for the manufacture of tin plate in the latter year. The south German (Bohemian) producers guarded the process for about 300 years, and it was not until about 1625 that the secret was obtained by the Elector of Saxony, in whose domains the industry soon became more important than in Bohemia. About 1665 an attempt was made to make tin plate in Great Britain, but not until 1720 to 1730 was the manufacture of tin plate in that country successfully established. Hanbury at Pontypool is credited with the first successful commercial production of tin plate in Great Britain. He is believed to have been the first to make steel plate by rolling. At first tin plate was produced in various parts of that island, but in recent times it has been confined to Wales.

Tin-plate manufacture began in France also early in the eighteenth century, about 1714.

For many years the United States imported most of its tin plate from Cornwall. According to Macnaughton and Hedges, not until 1873 was much progress made in commercial production in America because of lack of experienced labor and inadequate tariff. By 1897 United States production was 287,389 tons annually, and 1 million tons in 1912. It is now about 5 million tons annually. The McKinley Tariff Act (1890) included protection for American tin plate and gave the struggling industry the impetus required to enable it to reach its present great size.

While Cornwall was for several centuries the world's principal source of tin, since about 1870 the Malay States (now the Independent Federation of Malay) have become the most important source of this metal. Certain sections in South America, particularly Bolivia, and Central Africa also produce important amounts of tin. During the Second World War Bolivia was the principal source of tin ore. This supply was supplemented by the stock pile built up before the war and by recovery of tin from used tin cans.

Macnaughton and Hedges give the following description of the making of tin plate in Saxony. In the early centuries of tin-plate making, iron bars were hammered into thin sheets by hand. Later a number of the fairly thick sheets were hammered in bundles. The iron oxide scale was removed by rubbing with sandstone, followed by soaking in liquids acidified by fermentation. From this practice probably comes the modern term "pickling," which signifies treatment of the black plate in dilute sulfuric acid to remove oxide scale. The plates were scoured in water and sand and then stored in water until taken to the tinning pot. Three pots were used. In the first, or "soaking pot," of molten tin the plates were soaked for an hour or less; in the second, the "wash pot," they were redipped a short time to

give a more uniform coating; and in the third, the "list pot," the ends were dipped to melt and remove excess tin from the edges. The plates were then cleaned and polished with sawdust and moss. Later the molten tin in the soaking pot was covered with melted fat to prevent oxidation. The iron ore in Saxony was reduced to iron by heating with charcoal. Charcoal was subsequently replaced by coke in English practice. Hand hammering was replaced by rolling the bars mechanically to form plate in 1728.

During the nineteenth century dilute sulfuric acid replaced fermented liquids for pickling both the black plate and the descaled plate; Bessemer and open-hearth steel replaced iron for making the plate; special annealing methods for the steel plate were introduced; and zinc chloride flux came into use to facilitate union of the tin with the prepared steel-plate surface.

In the present century several important advances have been made. Some of these are the invention and perfecting of the sanitary double-seam can, electroplating, improved baked-enamel coatings, cellulose-lacquer linings, special wax linings, zinc oxide–containing enamels for corn cans, and the recently developed cold-rolled plate, which is very resistant to corrosion. Since 1943, according to Hartwell, all tin plate used for cans has been made by cold reduction (cold rolling).

Tin Conservation. During the Second World War the coating of steel plate with tin by electrodeposition and the making of bonderized tinless cans conserved tin, as outlined later in this chapter.

The use of tin for certain foods was forbidden. Glass containers displaced tin for many foods to a great extent. Tin in solder was displaced to some extent by silver.

Consumers were requested to save and flatten empty cans in order that they could be collected and delivered to detinning plants for recovery of the tin. For military use large amounts of fruits and vegetables were dehydrated and various other tin-conservation measures were adopted. According to Brighton et al., world production of tin since 1947 has exceeded consumption, a situation that has permitted the United States to stockpile it for a possible future emergency such as a global war. For further information, see Lueck (1942).

Base Box. Originally, according to "Steel Products Manual," section 14, it is likely that the early symbol "1C" may have stood for "one common," meaning 1 cwt. of tin plate of common grade. To give this weight 112 sheets, 14 by 20 in. was required. If the weight of the plate differed from the above, other symbols were used. Thus IX meant an increase in weight of 28 lb., or ¼ cwt. extra per 112 sheets. In time the unit consisting of 112 sheets of 14 by 20 in. became known in the trade as a "base box," or in Britain, a "basis box." The area of one surface of the sheets in a base box is 14 by 20 by 112, or 31,360 sq. in. (217.78 sq. ft.), or when both sides of the

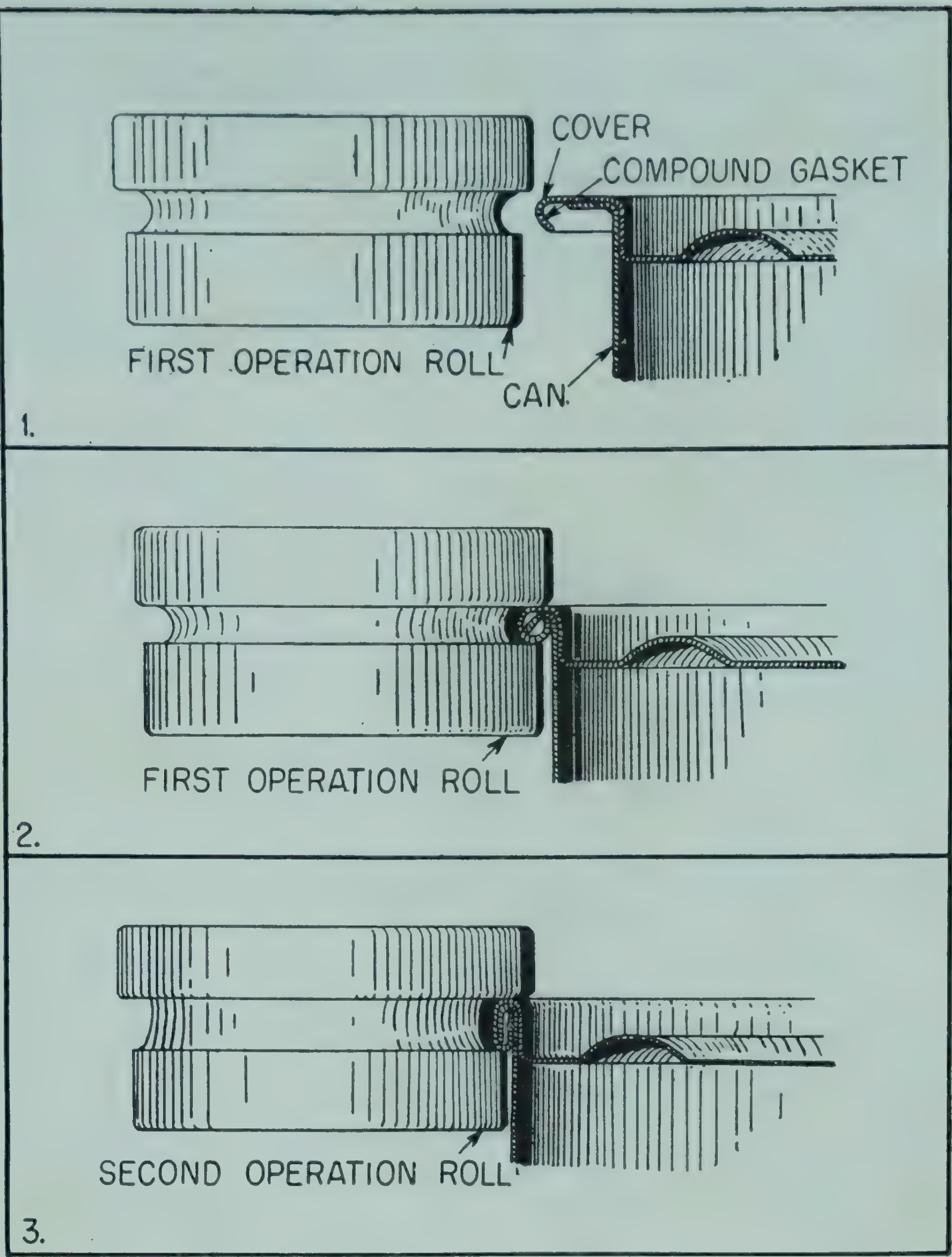


FIG. 3. Operations in sealing a can. 1. Before first roll. 2. First roll. 3. Second roll. (*After Cruess and Christie, Laboratory Manual.*)

sheets are considered, 62,720 sq. in. (435.56 sq. ft.), or 40.465 square meters.

The sheets in a base box weighing 100 lb. will be 0.110 in. in thickness and weigh 0.4952 lb. per sq. ft. Other weights per base box will vary accordingly.

Weights and Thickness of Tin Coatings. In America the weight of tin coating is usually expressed as pounds of tin per base box; in Britain as ounces or pounds and ounces per basis box; and on the European continent, as grams of tin per square meter. Thus 1 lb. of tin per base box would be equivalent to 1.04 grams of tin per square foot of surface, 11.2 grams per square meter, and 0.0367 oz. per sq. ft., corresponding to a thickness of 0.0000606 in., or 0.00154 mm. of tin coating; that is to say, the coating is extremely thin. See "Tin Plate Handbook" for conversion factors for other weights of tin per base box.

The amount of tin per base box is expressed either as the actual weight of

tin on the finished plate or the weight of tin added per base box to the tinning pot. This second figure is greater than the value found by analysis of the finished plate because of losses during tinning.

Plate that is coated with tin by hot dipping is classified as follows ("Steel Products Manual," sec. 14, p. 26):

Class designation	*Minimum average weight of tin per base box, lb.*
Common cokes (1.25 lb. pot yield)	0.85
Standard cokes (1.50 lb. pot yield)	1.05
Best cokes	1.19
Kanners special cokes	1.40
1A charcoal	1.80
2A charcoal	2.30
3A charcoal	2.80
4A charcoal	3.50
5A charcoal	4.20
Premier charcoal	4.90

Electrolytic tin plate carries much lighter tin coatings than the hot-dipped plate, as shown in the following tabulation:

Class designation	*Nominal coating, lb. per base box*
No. 25	0.25
No. 50	0.50
No. 75	0.75
No. 100	1.00

At present little No. 100 plate is made.

On a per cent by weight basis the quantity of tin on tin plate is small; thus for a base box weighing 100 lb. and coated with 1.4 lb. of tin, the per cent of tin by weight would be 1.4 per cent. For electroplate it would usually range from 0.25 to 0.75 per cent for tin plate weighing 100 lb. per base box. For the smaller cans much of the plate used weighs less than 100 lb. per base box.

The adjectives "coke" and "charcoal" that are encountered in publications on tin plate are used at present to indicate the weight of tin coating, but in the early days of the industry they referred to the fuel used in making the base plate. In making charcoal plate, charcoal alone was used as the fuel, whereas coke plate was made with a mixture of charcoal and coke as fuel. The early base plate was an iron rather than steel.

In 1875 Siemens open-hearth soft-steel plate was introduced, and according to Hoare (1950) still accounts for the major part of plate production, the remainder being Bessemer converter steel. The latter is often higher in P content, and on that account may be harder than the open-hearth steel. At present the term charcoal plate refers to comparatively

heavily tinned plate, and coke plate to the lighter, or common, coatings.

Steel for Tin Plate. The usual plate is a low-carbon steel made, as previously stated, by the open-hearth furnace process or by Bessemer converter. In California, at least, much of the raw material is scrap metal such as automobile frames and scrapped machinery of various kinds. Consequently, the resultant steel may contain small amounts of copper and traces of other metals. When copper steel is specified, a minimum of 0.15 per cent Cu is required.

Hoare states that Ni, Cr, and Cu are rarely added intentionally, but small amounts may arise fortuitously when low-alloy scrap steel is used in making the steel ingots.

Special steels are produced, one of the best known being Type L plate, used in making plate for cans for corrosive products such as berries, dried prunes, and certain juices. It is, according to Hoare, low in Si, P, and S.

The American Can Company has given the following usual composition, other than Fe, of Type L plate and of plain coke plate.

Constituent	Type L plate, %	Plain coke plate, %
Carbon	0.067	00.100
Manganese	0.370	0.350
Sulfur	0.032	0.040
Phosphorus	0.004	0.012
Silicon	0.003	0.005

Other special steels for tin plate are MR, similar to Type L but less restricted in residuals such as C, S, P, Mn, and Si; MC, rephosphorized or Bessemer steel to give higher temper; and M, similar to MC but hot-rolled. Types L, MR, and MC are cold-rolled ("cold-reduced"). Bessemer steel is often higher in P content than basic open-hearth steel.

Hot Reduction (Hot Rolling). Until a few years ago the steel plate for use in tin cans was made by the hot rolling of steel ingots to produce thin sheets suitable for tinning. Practically all steel plate for making tin cans, however, is now cold-reduced, i.e., made by cold rolling of steel that has been previously made into strips by hot rolling.

Ingots weighing up to 25,000 lb. each are made by casting the molten steel in special molds. The ingot is allowed to solidify, but while still hot is converted by rolling into slabs in the slabbing ("blooming") mill. Meneilly (1951) states that a slab is about 30 in. wide, 200 in. long, by 7½ in. thick and weighs about 2,000 lb. All slabs are cleaned by "hot scarfing" (flame blasting) to remove defective areas. The slab is heated to about 2200°F. and is then reduced in thickness and greatly elongated by repeated

rollings through a series of so-called roughing and finishing stands (rolls). The final thickness usually ranges from 0.065 to 0.100 in. The speeds of the various rolls are synchronized and adjusted for elongation of the moving strip of steel. The steel strip travels at great speed, according to Martin (1951); at more than a mile per minute in the latter stages of rolling. Scale (iron oxide) is removed by scale breakers, high-pressure steam, and water sprays.

Upon leaving the last set of rolls, the strip is coiled.[1]

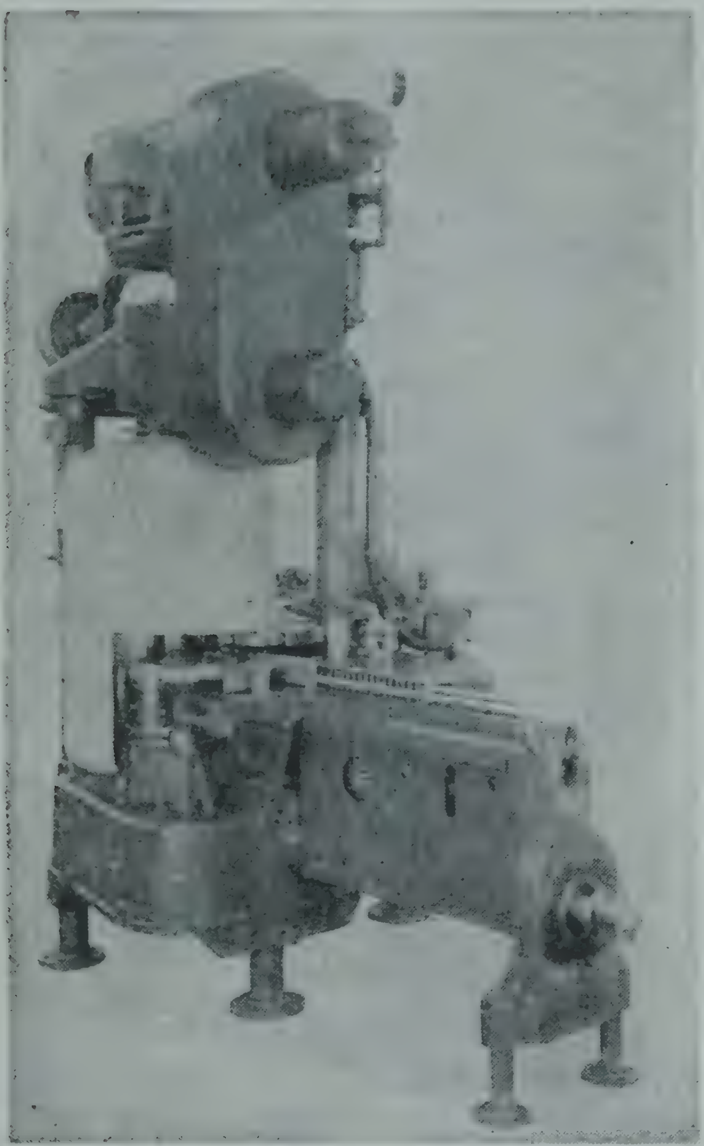


FIG. 4. Modern double seamer (closing machine) for cans. No. 450-HCM high-speed closing machine; left-front view. (*Continental Can Co., Inc.*)

Black Pickling. The coils of black plate are uncoiled, and the ends of several strips are welded together to give a strip several hundred feet in length. It is passed through a series of long tanks of dilute sulfuric acid to remove iron oxide scale and is then washed in sprays of water. The cleaned strip is then dried, oiled with palm oil, and recoiled. The oil tends to prevent rusting and serves as a lubricant during subsequent cold rolling.

Cold Reduction (Cold Rolling). The black strip is cold-reduced by passing it without preliminary heating through four or five stands of four-high tandem rolls. Palm oil is applied between stands to aid in reduction and prevent undue heating. Cooling is necessary as rolling increases the temperature of the steel. The final thickness of the plate varies according to its intended use, but is generally about 0.01 in.

The residual lubricant is removed by passing the strip through an alkaline bath or by electrolytic degreasing, because the oil would char during annealing.

As mentioned in another section, the rolls operate at great speed, the sheet traveling at 60 miles per hr. or faster toward the end of the rolling process. The rolls of coiled plate are large, weighing up to 30,000 lb. and standing 6 ft. on edge.

[1] Much of the information on manufacture of steel plate and on the tinning of steel plate has been furnished by Meneilly and by Martin. See references at the end of the chapter.

Annealing. Cold reduction creates a bright surface but also hardens the strip so that it is unsuitable for most can-making purposes. It is therefore annealed by a special heat-treatment to soften it somewhat and to remove strains induced in cold reduction.

In box annealing the coils of strip are placed in a closed metal box and slowly heated for several hours at 1200°F., according to Meneilly, with as complete exclusion of air as possible. An inert or slightly reducing gas is introduced into the box during heating and cooling to prevent undue oxidation of the plate.

In continuous annealing the strip is passed in single thickness through a series of vertical passes within a furnace containing both heating and cooling zones. The strip is heated rapidly to desired temperature and is cooled almost to room temperature before leaving the furnace. An inert or slightly reducing atmosphere is maintained in the furnace in order to prevent excessive black oxide–scale formation and thus maintain a bright surface.

Temper and Temper Rolling. Hoare states that temper of the plate, which has great influence on the formability of the plate and strength of the cans, is affected by various operations in tin-plate manufacture and is controlled principally by the composition of the steel and by the degree and type of cold rolling and final temper rolling. In the United Kingdom tin plate is available in (1) "deep-draining quality," extra ductile; (2) "deep-stamping quality," more ductile than quality 3 but less than quality 1; and (3) "ordinary stamping quality," the most common for general purposes.

In America according to the American Iron and Steel Institute, six classifications are made as follows:

Classification	Fields of use	Examples	Steel types
T_1	Soft steel for deep drawing	Drawn cans	L, MR
T_2	Shallow draws	Shallow drawn components	L, MR
T_3	General purposes	Can ends and bodies	L, MR
T_4	General purposes	Can ends and bodies	L, MR, MC*
T_5	Where stiffness is required	Large-diameter cans	L, MR, MC
T_6	Where stiffness is required	Beer-can ends	MC

* MC is not greatly used in T_4 plate.

It is possible to make a stiff-tempered steel by hard rolling or by limited rolling of steel of higher metalloid content. For example, steels T_1 to T_4 may be made of either Type L or Type MR steel, whereas T_5 and T_6 are obtained by use of steel high in phosphorus content.

In America temper rolling through a four-pass mill, or two such mills for tempering, follows the annealing of the plate. It is a cold-rolling process. Temper rolling improves the flatness of the plate, imparts the desired degree of stiffness and hardness, and produces the desired type and texture of surface.

White Pickling. If it is to be tinned by hot dipping, the strip is flattened by rolling, trimmed, and cut into pieces 20 by 28 in. in size. These are given a short bath in hot, dilute sulfuric or hydrochloric acid in order to clean and roughen the surface slightly so that the tin will adhere more evenly. The sheets are then rinsed with water and dried.

If the strip is to be electroplated, it is cleaned electrolytically in an alkaline bath and is then passed in a continuous manner through dilute acid, in which it is given a continuous electrolytic cold pickling, in order to give satisfactory electrolytic tinning. It is then rinsed and dried.

Hot Dipping. Hoare, of Tin Research Institute, describes hot dipping about as follows: The tinning unit is made up of a thermostatically controlled, directly heated tank containing molten tin, in which are submerged rollers and guides that conduct each sheet downward through a layer of zinc chloride flux into the molten tin and then upward through a thick layer of palm oil. As the sheets pass through the palm oil they are given a "squeegeeing" action by tinned steel rolls which serve to regulate the final thickness of the coating. These rolls operate in a bath of palm oil. For more heavily coated tin plate a second dip is given.

Cleaning. The sheets are cooled after dipping and are then cleaned to remove adhering oil. This may include passage through an alkaline bath before branning. A branner consists of several rolls covered with felt, flannel, or other suitable material over which wheat or rye bran or middlings or wood meal (clean sawdust) is distributed continuously as the tinned sheets pass through the rolls.

Inspection. The cleaned sheets are then carefully inspected for flaws and defects and packed for delivery to the can-making department. Each line is equipped with automatic equipment to detect sheets that have small holes or are of improper thickness or otherwise defective.

Electroplating (Electrotinning). By the hot-dipping process it is not possible to secure an absolutely uniform coating of tin nor a very thin coating such as one of 0.25 lb. of tin per base box. By electroplating, a very uniform coating of 0.25 lb. or less of tin per base box is readily attainable. By replacing the common grade of hot-dipped plate of 1.25 lb. tin per base box with the electroplated of 0.50 lb. tin per base box, a saving of about 60 per cent in tin is attained. On this account electroplating has

come into very general use in recent years because of the shortage of the world's supply of tin and its high price. Martin (1951) has described electroplating, as have also Brighton et al. (1954).

The coils of cold-rolled strip steel plate are uncoiled, cleaned, given a light electrolytic pickling in dilute H_2SO_4 or HCl, and tinned in a continuous manner by passage through a series of electrolytic cells filled with either dilute acid or dilute alkali. The tin for plating comes from massive electrodes of pure tin that are immersed in the electroplating cells. Direct current of suitable voltage and amperage causes the tin from the tin anode to dissolve slowly and plates it out on the cathode, which is the moving steel strip. The tin coating at this point is dull in finish. To give a bright finish suitable for food cans it is fused, i.e., flash-melted, by momentarily melting the tin by electricity by conduction, or by radiant heating, or high-frequency induction, an electrical process. It is then chilled quickly and treated briefly in a chromate bath, rinsed, dried, and given a very thin coating of oil. It may then be coiled and sent to the can-making plant or may be uncoiled, trimmed, cut into sheets and the sheets inspected, classified, and packed for delivery to the can-making factory.

In differential electroplating a light coating such as 0.25 lb. tin per

FIG. 5. Common forms of commercial glass containers.

base box may be applied on one side of the plate and a heavier coating such as 0.75 lb. per base box to the other side. Munns (1951) states that this differential coating is accomplished in a horizontal two-deck electroplating machine, each deck containing a series of electroplating cells. One side is plated in the first-deck cells, and the other in the second. The more heavily plated side will form the inside of a can made from such plate, as the outside is not subject to the corrosive action of the food product.

Corrosion Resistance. Hartwell (1951) has stated that the largest part of the tin plate used today is electrolytically plated. He also has pointed out that the lightly electroplated coatings of 0.5 and 0.25 lb. per base box must be enameled for use with fruits and other relatively corrosive products, in order to secure adequate shelf life.

Even the heaviest coating of 1 lb. per base box does not have as good corrosion resistance as hot-dipped plate of similar weight of tin coating. Also, according to Hartwell, it is much more erratic in its resistance to corrosion, some cans showing a much greater tendency to corrode than others. Hartwell states that oxidizing influences during annealing apparently have an important bearing on this erratic behavior. He points out that operations conducted on the electrotinning line before the final electroplating is made may not give the same result as the hot pickling and fluxing treatments to which plate sheets for hot dipping are subjected. However, electroplate has been greatly improved in recent years in respect to corrosion resistance.

Nevertheless, for the reasons noted earlier in this section, all electroplate used in making can bodies for even mildly corrosive foods is enameled.

Electrolytic plate with the lightest commercial coating of 0.25 lb. per base box is now used very successfully for dog foods, a very important product, and for enamel-lined beer cans, a product requiring about 5 billion cans annually. Stevenson states that for such fruits as peaches, pears, and fruit cocktail, enameled, electroplated ends may be used with hot-dipped bodies, a combination that gives very satisfactory shelf life.

Can Linings.[1] Although cans made from plain tin plate are suitable for many food products, some are adversely affected by the metal, or adversely affect the container by excessive corrosion or by causing a deposit of black iron sulfide, such as occurs with corn and certain sea products. Some foods bleach in color in plain tin cans. In some foods the slight bleaching action of plain tin plate is desirable, as for canned sauerkraut, grapefruit segments and juice, peaches, and pears.

Additional coatings over hot-dipped tin plate are also used for some foods. The coating for both types of plate includes certain oleoresins, vinyl plastics, so-called phenolic plastics, and special waxes (the last-named in

[1] The author is indebted to S. L. Flugge for much of the information in this section. See reference list at the end of the chapter.

beer cans). Attempts to find a single, universal all-purpose coating have failed.

A can lining should be nontoxic; free from flavors or odors that might adversely affect the food; resistant to the products to be canned and supply an effective barrier between food and metal; readily applied and rapidly cured on various types of plate and various styles of cans; resistant to mechanical actions of can making and can sealing; and finally, economical in cost. The coating must be as continuous as possible because, if very small areas of metal are exposed, corrosion will be concentrated at those points and there will be possible liberation of enough hydrogen to adversely affect the vacuum in the can or to result in pinholing of the plate.

Certain foods may cause peeling of some enamels; for example, a product packed in oil or high in oil content may have this effect if an inappropriate enamel is used.

Most enamels are applied in solution to the flat tin sheets by means of roller coaters, and the sheets are baked in continuous ovens. The enameled sheets are then made into cans. Can making subjects the plate to severe bending, drawing, and frictional forces; therefore the enamel must be relatively scratch-resitant and must not peel under bending stress. Some enamels such as very hard waxes are too brittle to stand bending. The lining should also not char too badly from the heat of the soldering operation on the side seams of the can body.

For some products the interior of the finished, enameled can is sprayed with enamel and baked again to give a "reenameled" or "double-enameled" can. So-called berry enamel is usually of this type.

The usual enamel, according to Flugge, is very thin, 0.0001 to 0.0004 in. thick, and weighs from 4 to 6 mg. per sq. in. Baking temperatures are usually not above 420°F., 380 to 400°F. being a common range. Tin melts at 450°F.

While accelerated laboratory-scale tests are valuable in evaluating new enamels, a pack of considerable size of the canned product under commercial conditions is also necessary before approval or rejection is made.

Because of the present scarcity of tin and widespread use of electrolytic plate, the trend has been to electroplate the tin plate for can ends with a light coat of tin and to give the plate used for the body a heavier coating. Such cans are now in common use for certain fruits, the inside coating of the body being 0.5 lb. of tin per base box, the ends being coated with 0.25 lb. of tin per base box. The outside coating of the entire can is 0.25 lb. per base box.

In the past a natural resin such as Japanese lacquer gum and tung oil, a drying oil from tung nuts, was the principal ingredient of can enamels. A considerable number of phenolic resins, oleoresins, petroleum resins, and epoxy-type resins have come into use, as previously mentioned. These are

synthetic products or naturally occurring products modified by chemical treatment or other means.

For canned products that liberate H_2S during sterilization an enamel containing about 15 per cent of zinc oxide, so-called "corn enamel," or "C-enamel," is used to prevent discoloration of the plate by black FeS. Zinc sulfide is white.

Vinylite resins, because of their flexibility and complete lack of off flavor and odor, are in general use for certain products, including beer, that are not subjected to high temperatures. Vinyl coatings should not be heated above 200°F. as at higher temperatures a white blush forms in the coating. Modified vinyls that are more resistant to heat are now available, according to Flugge (1951).

A special wax lining is in use for beer cans made by one leading can manufacturer. The melted wax is applied to the inside of the finished can and allowed to harden on cooling. It withstands beer-pasteurizing temperature of about 140°F. but melts well below 212°F.

Testing Tin Plate. The American Iron and Steel Institute recommends taking of one plate at random from each 50 packages with a minimum of three plates for the composite sampling. From each plate three samples of 4 sq. in. each are cut from each sheet diagonally across the plate. Each sample is weighed to obtain the weight of the plate per base box at each sampling point. The thickness of the tin coating or the weight of tin per base box can be determined, according to Meneilly, by X-ray analysis. An X ray of proper wavelength and intensity is passed through the tin coating, reacts with the underlying steel plate, and is reflected, causing fluorescence, the intensity of which varies with the thickness of the tin coating. This can be measured by means of a suitable radiation detector. Or the tin may be dissolved chemically from a weighed sample and determined in the resulting solution by gravimetric or volumetric analysis, such as described in any textbook on inorganic quantitative analysis, or in the booklet Determining the thickness of tin coatings, *Tin Research Institute Publication* 115.

Outline of the Manufacture of Sanitary Cans. The sanitary, or open-top can, which is sealed by double seaming without the use of solder, has become the most important food container now used.

Cutting Body Blanks. The sheets are cut by a slitting machine into strips equal in width to the circumference of the can. These strips are cut crosswise to form the body blanks. The machine used for this purpose is known as a "gang slitter." A slitter and trimmer will produce about 75,000 body blanks per day.

Notching Body Blanks. Each body blank is notched at the four corners in such a manner that smooth joints are formed at the junction of the two edges of the body, when the lap seam has been made. This smooth union

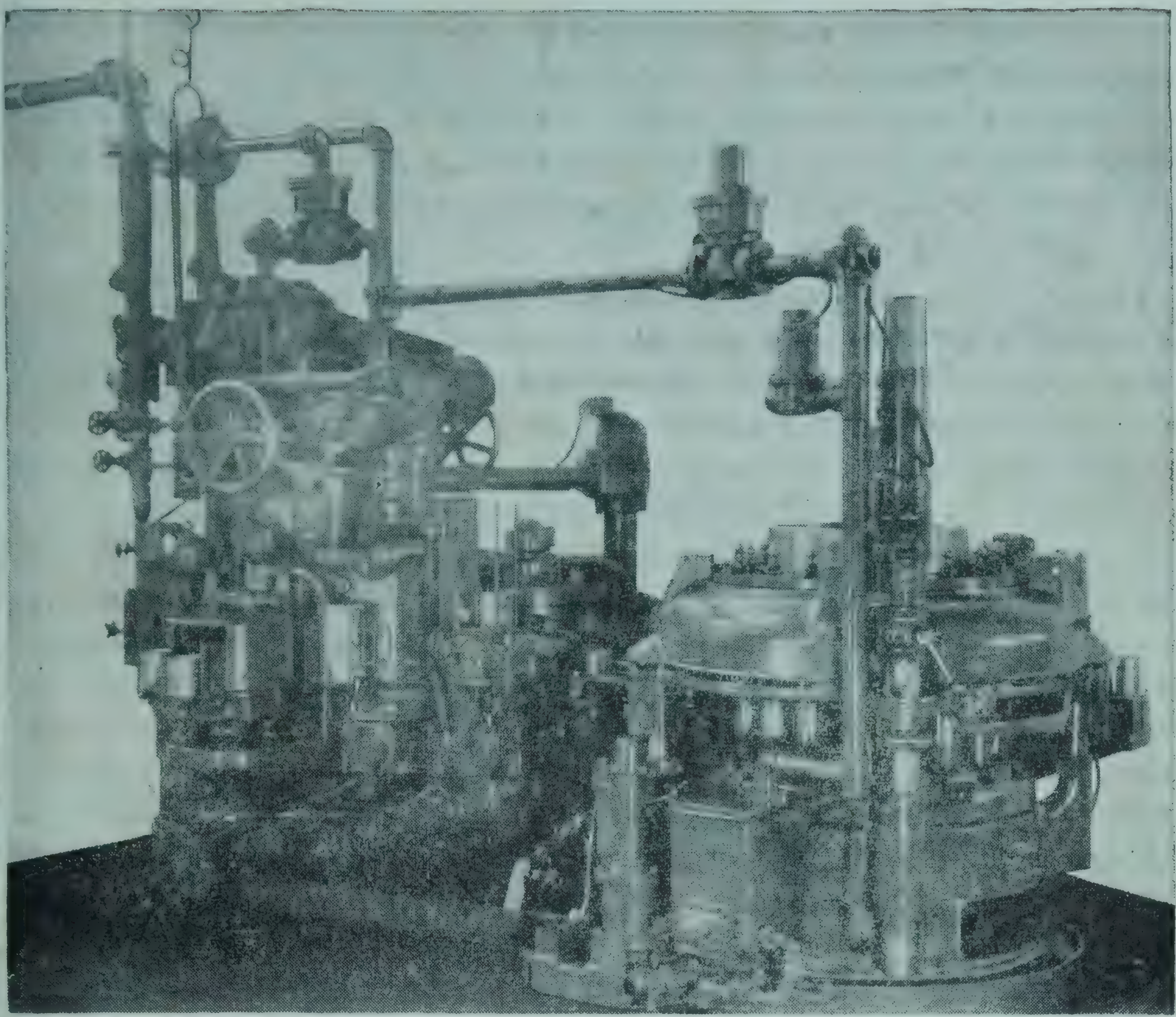


FIG. 6. Vacuumizing unit and vacuum-sealing machine. (*American Can Co.*)

is essential in order that the ends of the can may be smoothly double-seamed to the body without danger of leaks.

Lock Seaming. The flat can body passes through an edging device, which is usually part of the lock-seaming machine. The edges are turned back, and when the can body is turned around the horn or mandrel, these edges hook together. The body is bent around the horn by "wings," moving metal sheets. A hammer drops upon the locked edges and flattens them, forming the lock seam. Since the lock seam is not water- and gas-tight, the can body is carried forward in such a manner that the seam passes through flux and molten solder. The excess solder is then removed by brushes, and the can bodies are cooled by a blast of air.

Flanging. The can bodies next pass through a flanger, a machine equipped with convex plungers, which are forced a short way into the open ends of the can body, forcing the edges outward to form the flanges, which are to receive the ends.

Forming the Ends. A machine known as a "scroll shears" cuts the tin plate into strips of a pattern resulting in a minimum of waste.

A stamping machine known as an automatic vacuum "strip-feed press" receives the strips and stamps out the disks that form the ends of the cans. It also forms the panels, concentric circular ridges, and depressions on the can ends, giving rigidity to the ends and reducing bulging. The edges are still flat. From the press the ends pass to the end-curling machine, which curls the edges of the can ends inward.

The Gasket. A solution of rubber composition in benzene or toluene is placed in the groove of the can end and is dried quickly by heat. A film of rubber composition is left in the groove and forms the "rubber gasket."

Instead of the rubber composition, a paper gasket may be cut from thin spongy cardboard and fitted to the groove. The paper gasket is used but little at present for food containers.

Sealing the Ends. The can bodies and one end are brought together in the double seamer. The can body enters the double seamer in a horizontal position; the end is applied automatically, and small rollers pass around the edges of the end and can body, folding the flanges of the end and can body as shown in Figure 3, *2*. A second pair of rollers then pass around the edge of the can and tightly compress the folded flanges together, as shown in Figure 3, *3*. To form an airtight seal, pressure at the same time is exerted against the end of the can, forcing the gasket tightly against the end.

The end sealed to the can in the can factory is known as the "factory end," and that sealed in the cannery, the "cannery end." The sealing operations are known as double seaming, and the seal as a double seam.

Testing for Leaks. The finished cans are fed to a testing machine, which automatically places the open end of the can against a large rubber gasket and applies air pressure. Leaky cans are thrown out by the machine. The defective cans are tested further by workmen who repair the leaks and again test the cans before they are sent to the warehouse or cannery.

Can makers usually guarantee that there will be less than one defective can in 1,000.

Sizes of Cans. Tin cans are made in a great variety of sizes and in several shapes such as cylindrical, oval, and "square" and have been developed by trade custom rather than by the needs of the consumer. However, certain sizes are much more common than others. Table 1 gives most of the sizes used, as given by the American Can Company (1949).

In recent years the 303 size can has attained great popularity for peas, corn, fruits, and tomatoes, largely replacing the No. 2 for some products. The 8-oz. can is used very extensively for tomato hot sauce, and is also popular for fruit cocktail. The No. 2½ can is very popular for canned fruits; the No. 2, No. 1 Tall, 303, and 8-oz. are also used, especially for sliced fruits. Olives were formerly packed in tall pints and tall quarts, but at present the 211, No. 1 Tall, and 8-oz. are in common use. Tomato juice

is often packed in No. 5, 303, and No. 1 Tall cans. Grapefruit juice is commonly canned in No. 2 and No. 5 cans. The No. 10 can is used for all varieties of fruits and vegetables for institutional use, i.e., for hospitals, restaurants, hotels, passenger ships, the military, and others. The Picnic, or Eastern Oyster, size is used for other products in addition to oysters; it is 2 11/16 by 4 in. in size and holds about 10 fl. oz. of liquid food product (Table 1).

In Table 1 the capacities in fluid ounces are average commercial fills; actual capacities are somewhat higher.

TABLE 1. SIZES AND CAPACITIES OF STANDARD CANS

Can name	Diameter, in.	Height, in.	Canners' designation	Net contents, fl. oz. of liquid product
2 Z Mushroom	2⅛	2¼	202 × 204	3¼
6 Z	2⅛	3½	202 × 308	5¼
5 Z	2 11/16	2	211 × 200	4
4 Z Mushroom	2 11/16	2¾	211 × 212	6½
8 Z Short	2 11/16	3	211 × 300	7
8 Z Tall	2 11/16	3¼	211 × 304	7¾
No. 1 Picnic	2 11/16	4	211 × 400	9½
No. 211 Cylinder	2 11/16	4⅞	211 × 414	12
Pint Olive	2 11/16	6	211 × 600	15
4 Z Pimiento	3	1½	300 × 108	3¾
7 Z Pimiento	3	2⅜	300 × 206	6¾
8 Z Mushroom	3	4	300 × 400	12
No. 300	3	4 7/16	300 × 407	13½
No. 303	3 3/16	4⅜	303 × 406	15
No. 1 Tall	3 1/16	4 11/16	301 × 411	15
303 Cylinder	3 3/16	5 9/16	303 × 509	19
No. 2	3 7/16	4 9/16	307 × 409	18
No. 2 XT	3 7/16	5⅜	307 × 506	22
No. 2 Cylinder	3 7/16	5¾	307 × 512	23
No. 2 Tall	3 7/16	6¼	307 × 604	26
Quart Olive	3 7/16	7¼	307 × 704	30
No. 2½	4 1/16	4 11/16	401 × 411	26
No. 3 Cylinder	4¼	7	404 × 700	30
No. 5	5⅛	5⅝	502 × 510	52
No. 10	6 3/16	7	603 × 700	96

SOURCE: Courtesy of American Can Co.

Untinned Plate (Black Plate). For many years cans have been made of untinned steel plate for certain nonfood products, such as nails, bolts, paints, etc. During the Second World War, because of the cutting off of

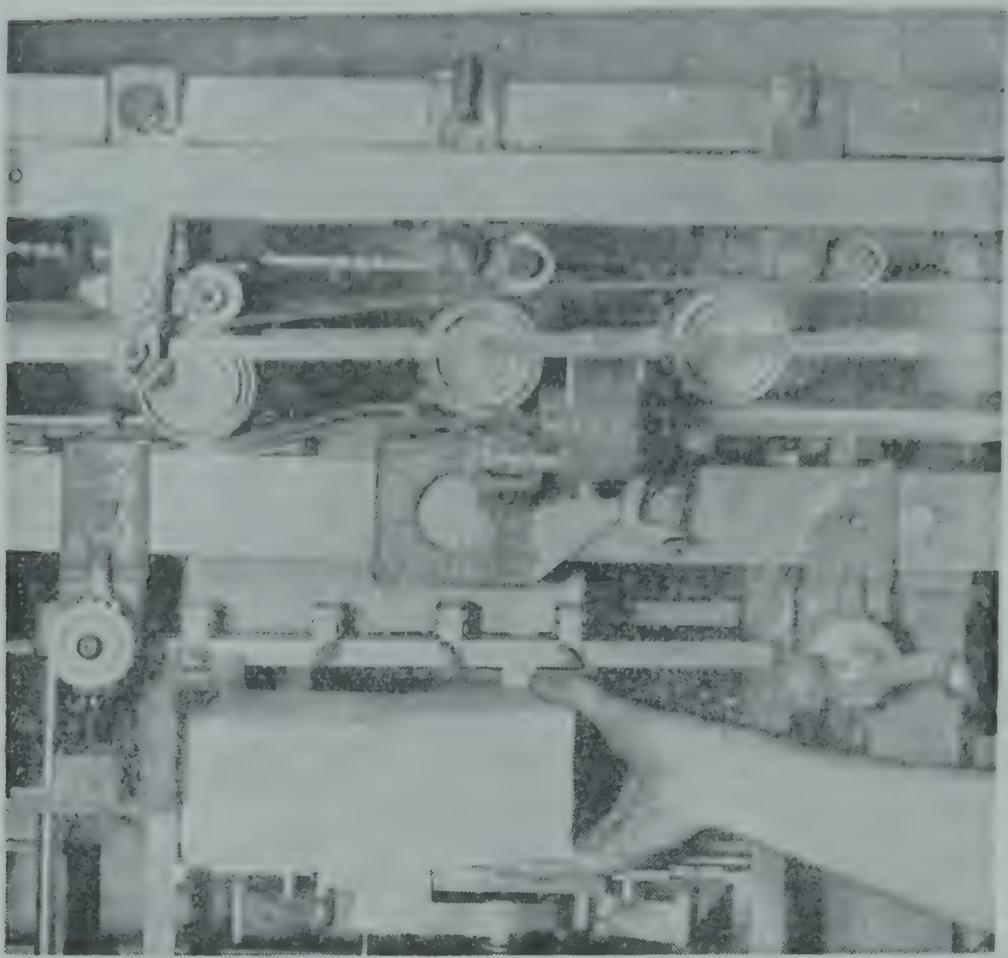


FIG. 7. Close-up of can labeler in operation. (*Burt Machine Co., Baltimore.*)

tin imports from the Far East, the use of cans made of untinned steel was investigated intensively and considerable progress made. Acid foods attack the untinned steel, but certain food products of low acidity, such as certain vegetables and ripe olives, have been packed successfully in cans made of untinned steel that had been treated chemically and enameled. The chemical treatment, according to Lueck (1942), consisted in heating the plate in a phosphate solution which formed a protective coating of complex phosphates. The purpose was to give a surface to which can enamel would adhere well. The process was known as "bonderizing."

After cleaning and drying, the plate was coated with a suitable can enamel and baked.

It is difficult to solder the side seams of black-iron cans, but Brighton et al. report (1954) that the side seam may be welded by heat and that recently certain true thermoplastic cements have been found that are satisfactory for sealing the side seams without use of solder or welding.

The outside surface of the cans may be lithographed, a familiar example being the quart cans of cylinder oils found in gas service stations. The bonderized cans made during the war were heavily coated inside and outside with an enamel that was baked on. Not all can enamels adhere well, but Brighton et al. state that excellent progress has been made in developing enamels for black-plate cans that stand up well in the canning and retorting (sterilizing) of nonacid food products.

Aluminum Cans. Because of the very low cost of electric power in Norway, sheet aluminum is made into cans, used principally for fish. The cans are made by drawing or by impact extrusion, according to Brighton et al.

Aluminum sheet has been made into cans by tin-can-making methods, but this metal is extremely difficult to solder or weld for closing the side-seam. However, recently developed cements such as used for black-plate cans may solve this problem for aluminum food cans. Aluminum is very soft as metals go, is of low tensile strength, and difficult when used for cans to double-seam without tearing.

Steel plate has also been coated successfully with aluminum, but as yet, apparently, it is not commercially practicable. Eventually, aluminum-clad steel cans or all-aluminum cans may be perfected and used to replace or supplement the use of tin cans.

Zinc coatings are soluble in many food products and in such cases would be poisonous.

Nickel-plated steel cans perform well, but nickel is too scarce and too costly at present for such use.

Other Containers. Plastic film, cardboard, and so-called "paper cans" are used as materials for containers for frozen fruits and vegetables. These materials and wood are used for containers for dried foods. Containers for frozen fruits and vegetables are discussed in Chapter 25, and those for dried fruits and vegetables in Chapter 20.

GLASS CONTAINERS

The glass container possesses the advantages that there is less metal to react with the food product, the customer may see in the unopened container what he purchases, and the container is refillable. It has the disadvantages that it is heavier and more fragile than the tin container. Its uses in the food industries have been mentioned.

Glass was known to the ancient peoples of the Mediterranean basin as early as 1600 B.C. Probably the first glass was made by mixing sand and the ash of seaweed, covering with clay, and heating in a furnace. After cooling, the ball of pottery was cracked open to secure the lump of glass. Later the ingredients were mixed, wet-molded, and burned in the same manner as pottery.

Composition. Glass may be defined as a neutral solution of silicates formed by heat and fusion, with subsequent cooling to prevent crystallization. Part of the silicate may be replaced by borate or phosphate. Glass for food containers usually consists of silicates of sodium and calcium, with small amounts of aluminum oxide, borate, and barium silicate. If magnesium oxide is included, the hardness of the glass is increased. Wright

gives the following formula as typical of those used at present in the making of glass for food containers:

Ingredients	*Per cent*
SiO_2	72.70
CaO	10.40
Na_2O	13.60
K_2O	0.40
Al_2O_3	2.00
FeO	0.06
BaO	0.50
SO_3	0.30
F_2	0.20

SOURCE: "Handbook of Glass Manufacturers."

Phillips gives the following formula for food-container glass:

Ingredients	*Per cent*
SiO_2	70.40–75
Al_2O_3	0.50–3.10
CaO	4.6–9.70
MgO	0.30–4.30
BaO	0.10–0.60
Na_2O plus K_2O	15.0–17.0

Evidently there is quite a large range in the percentages of several of the ingredients. Although the oxides of the alkali and alkaline earth metals are given in the formulas, usually the carbonates are used.

Modern containers made of glass are of much greater resistance to mechanical shock (far less brittle) and to heat shock than glasses of, say, twenty-five years ago. Therefore bottles and jars now have much thinner walls than formerly and therefore are much lighter in weight.

Some of the older formulas called for inclusion of a small amount of manganese dioxide to mask the brownish color imparted to the glass by small amounts of iron in the sand or other raw ingredient. Present formulas appear to omit the manganese, perhaps because of the higher purity of the raw ingredients now in use.

There are many special glasses, one of the best known being one sold under the trade-mark Pyrex. It consists, according to Phillips, of the following:

Ingredients	*Per cent*
SiO_2	80.5
B_2O_3	12.9
Na_2O	3.8
K_2O	0.4
Al_2O_3	2.2

Such glass is known as a borosilicate glass and is only one of a considerable number. The borosilicates have roughly one-third the heat expansion of ordinary glass, great resistance to heat shock, high electrical conductance, and excellent chemical stability. Therefore they are very useful for kitchen utensils and laboratory glassware, but somewhat too costly for common jars and bottles.

Barium gives a heavy glass of high refractive index, useful in optical instruments. Lead imparts weight and brilliance, useful in cut glass. Zinc imparts toughness and heat resistance.

Color is imparted by various elements. Thus ferrous iron gives a green glass, ferric a brown, chromium a green, manganese dioxide a pink, cobalt a blue, cadmium sulfide a yellow, carbon an amber, and uranium a fluorescent yellow glass.

The Mix. While the alkali and alkaline earth elements used in glass making are given in formulas as the oxides, according to Griswold, they are generally used in the mix as carbonates, such as soda ash, Na_2CO_3, and limestone, $CaCO_3$, although Ca can be used also as the oxide CaO. Boron is used in the form of borax, $Na_2B_4O_7.10H_2O$; aluminum is used as pure kaolin, $Al_2O_32SiO_22H_2O$, or as alumina hydrate, $Al_2O_33H_2O$, or feldspar, $K_2OAl_2O_36SiO_2$.

Silica sand is essentially silicon dioxide and furnishes the SiO_2 of glass. It should be practically free of Fe, according to Griswold, a requirement that makes many sands unsuitable. The raw materials are carefully analyzed, and the proportion of each required in the batch mix is calculated.

A very important ingredient of the raw mix is cullet, which is crushed glass. It represents defective containers that are culled out as the new containers are sorted, old second-hand containers from various sources, and the glass left in the furnace when it must be torn down for rebuilding. Phillips states that cullet may constitute as much as 75 per cent of the mix, very often 50 per cent, and seldom less than 25 per cent. Since cullet may vary considerably in composition, it must be used with care in order that the final composition and quality of the glass may be satisfactory. It is crushed and generally stored in bins until used.

According to Phillips and other references, the raw materials are usually stored in large bins but may be carried in heaps in large partitioned rooms.

The raw materials are conveyed by direct chute or by belt from the bin to automatic scales (a hopper and automatic scale), by a separate line for each; the raw materials are transported by overhead rail and buckets or by belt to the batch mixer. The mixer is power-driven and may be of the barrel type or pan type, according to Phillips. The ingredients must be very thoroughly mixed, 4 min. mixing for most batches, but as long as 15 min. for those containing barium oxide or zinc oxide.

The mixed batch, as observed in California plants, is transported to the

furnace by bucket conveyer and crane or overhead rail and bucket or by other means.

Melting. The mix is melted in a long deep tank-type furnace lined with refractory brick and fire clay or other refractory (heat-resistant) material. While it makes glass production possible by providing a heat-resistant "tank," or "pot," in which the glass can be melted, it also is responsible, according to Griswold, for the principal defects of glass because the refractory is gradually dissolved by the molten glass. There are a considerable number of refractories, but they may be classified as acid, basic, and neutral. Silica brick is acidic, while magnesite brick is basic. High alumina and fire-clay brick are classified as neutral.

The walls, ceiling, and floor of the tank furnace are massive; nevertheless they gradually "wear out" by erosion and corrosion and periodically must be torn down and rebuilt, a costly and time-consuming operation.

Furnaces are of two types: (1) tank furnace, and (2) pot. Glass for food containers is made in tank furnaces since the pot furnace is relatively small and is used for special glasses. The tank furnace, as observed in California plants, consists of a long rectangular covered furnace heated by gas or crude-oil flame, generally applied by regenerative firing, in which the flame and hot gases pass through a large regenerative chamber filled with "open-work" refractory brick. This material is heated almost to furnace temperature, and the direction of flame flow is then reversed, to pass through another regenerative chamber on the opposite side of the furnace. Air necessary for combustion is drawn through the first regenerator and heated by the hot brick, and in this manner the fuel efficiency is greatly increased. The direction of flow of the flame is reversed rather frequently. Phillips states that of the total heat generated in the furnace rarely is 25 per cent utilized, seldom is it above 15 per cent, and it may be as low as 5 per cent. The flame heats the mix largely by direct contact as it passes over its surface in the tank.

The batch is fed into the "cool," or "melting," end of the furnace through a boxlike chamber ("doghouse") extending beyond the end wall. In this end of the furnace is a shallow pool of molten glass, partially melted mix, and fresh unmelted mix. From this area the molten glass travels slowly through a submerged throat into the refining chamber. From this chamber molten glass is drawn for making bottles and jars.

Gases are liberated from the carbonates, hydrates, nitrates, and sulfates of the mix. These bubble through the molten mass and escape with the gases of combustion, violently agitating the molten glass. Complete fusion and mixing finally occurs, but sufficient additional time must be given to allow the small gas bubbles to escape; rapid melting and high furnace temperature favor rapid escape of these fine bubbles. According to the

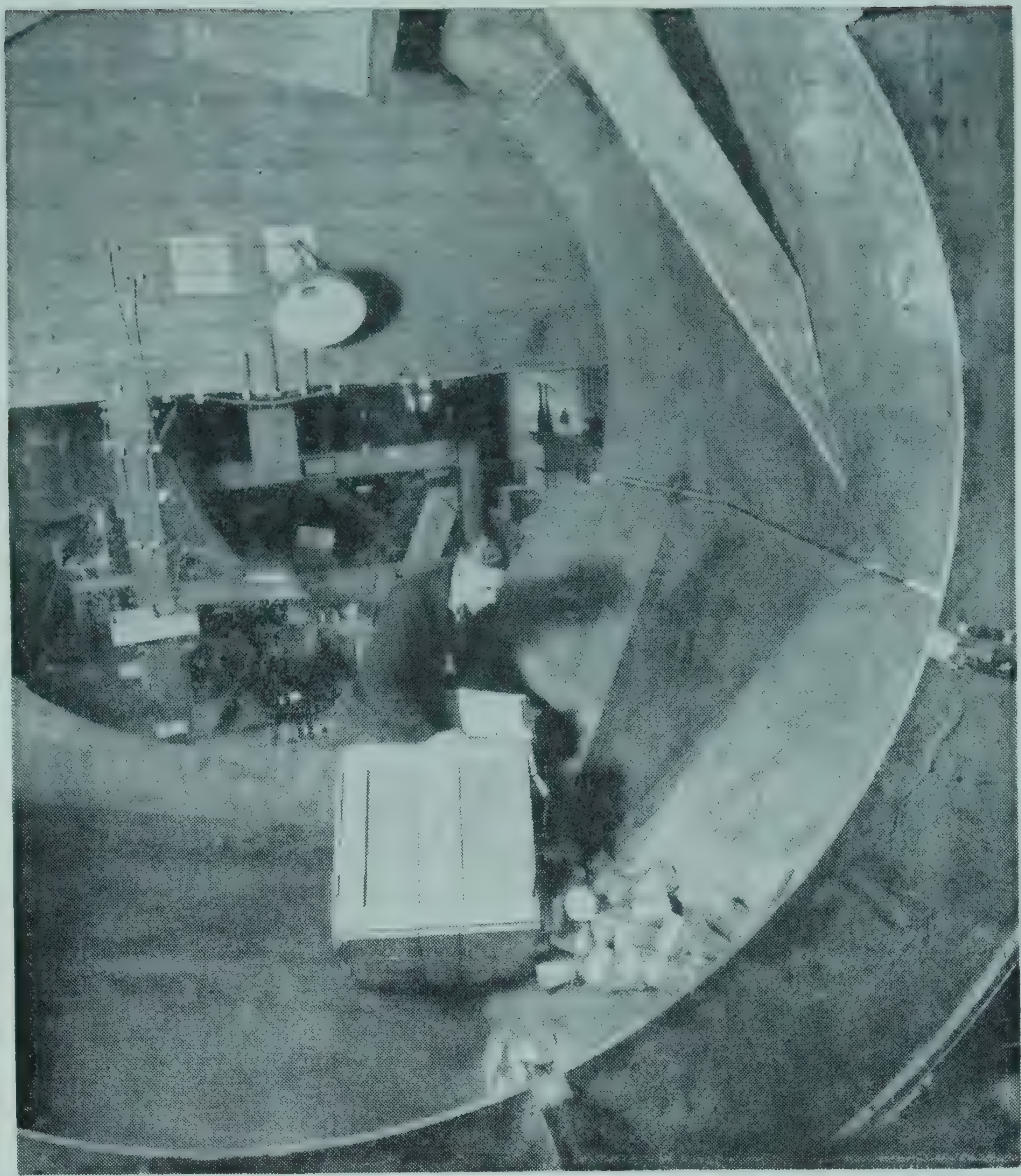


FIG. 8. Failure of canned-foods box in box-testing drum. (*Forest Products Laboratory, Madison, Wis.*)

Glass Container Institute, the temperature usually exceeds 2700°F. The operation of the tank furnace is continuous on a 24-hr. basis.

Forming Glass Containers. In one method of formation of the bottle or other container, as observed in a large California factory, the molten glass flows into a very large revolving bowl from which it is sucked up into the metal molds of a rapidly revolving forming machine. In another, perhaps more common, procedure, the molten glass flows from the tank furnace into mechanical feeders which turn out red hot "gobs" of glass of accurately measured volume and taffylike consistency. The red-hot gob is cut free and drops into a waiting "blank" mold in which it is blown by compressed air or is pressed by plunger into a rough approximation of the finished container called a "parison," according to Smith. This mold is then inverted and releases the parison, which falls into a second, or finishing, mold in which it is blown by compressed air into final shape. A blast of flame then fire-polishes the mouth of the container. The mold with the

newly blown container is carried automatically to the delivery point for transfer to the annealing oven.

During this brief interval the glass hardens sufficiently to enable the container to stand without buckling or sagging. The jaws of the mold then open, and the dull-red-hot container is deposited gently on a slowly moving woven-wire conveyer that transports it to the annealing oven, or "lehr."

At one time a good many simple containers of ordinary jelly-glass form were made by pressing the molten glass in a metal form; but at present, according to the research staff of a large glass manufacturer, most food containers, including jelly glasses, are formed by one of the two-stage procedures of "press and blow" and "blow and blow" described above.

Annealing. Annealing, or tempering, is one of the most important steps in the making of glass containers for foods, for upon it depends in very great measure the resistance of the glass to breakage during cooling and to breakage by mechanical shock, i.e., rough handling.

On removal from the finishing mold some parts of the container will be hotter than others and a temperature gradient will exist between the surface and interior of the container. If cooled to room temperature in the open air, some parts of the container will be under strain and it will be very liable to break under shock and heat. Therefore it must be annealed. This consists in reheating it to a constant temperature within the annealing range of temperature so that strains due to uneven temperature are removed and, secondly, to cool the glass at such a rate that no, or very little, new strain will be developed.

Smith[1] states that in the upper part of the annealing range of temperature the glass is so fluid that it yields almost instantaneously to stress, and a strain cannot persist. The lower limit of the annealing range is called the "strain point," below which the glass may be cooled quickly without producing permanent strain.

In commercial practice the containers are conveyed by a heavy woven-wire belt through a long brick tunnel heated by gas flame under very accurate automatic temperature control. The containers are first heated to about 1000°F. and remain at this temperature for a few minutes until the glass is of uniform temperature and free of strains. As it travels forward the temperature then progressively decreases until the containers emerge at a low enough temperature to be handled with heavy gloves.

The annealed containers are examined very critically on emergence from the lehr. If even a very minute flaw is found, the container is broken and goes to the cullet bin. In addition, many samples are taken throughout the 24-hr. operating day and subjected to various tests in the laboratory to determine accuracy of net capacity, resistance to mechanical shock and

[1] Personal communication.

temperature shock, accuracy of contour of top, imperfections in the glass, and other factors.

As Griswold[1] states, strain in glass can be detected by its effect on a beam of polarized light. Polariscopes of proper design are available and used for this purpose.

As previously mentioned, as a result of improvements in glass formulas, furnace practice, annealing, and other operations, modern glass containers are much lighter in weight than formerly and of remarkable resistance to shock and heat. In one California plant glass jars of fruit cocktail are sterilized under pressure in a continuous retort at temperatures above 212°F., and sterilization in still, discontinuous retorts at 240 to 250°F. of ripe olives, vegetables, and meat products in glass is common practice. See also Chapter 7 on processing of canned fruits and vegetables.

Defects of Glass. Phillips, Griswold, Smith, and others have described the following defects of glass. "Seeds" consist of small bubbles of gas, less than $\frac{1}{16}$ in. in diameter; if larger, they are "blisters." This defect may be due to too short a stay in the furnace or too low a furnace temperature.

"Stones" consist of nonglassy material imbedded in the glass which may be bits of the refractory of the furnace walls or due to devitrification. They may be detrimental to appearance and strength of the glass.

"Cords" are narrow bands in the glass that have an index of refraction different from that of the main body of the container and are due to differences in composition from faulty melting practice in the furnace or to very faulty annealing.

Brittleness and low resistance to temperature shock are usually due to poor annealing.

"Fins" are ridges formed by improper matching of the mold seams. "Scale" consists of small particles on the glass surface, usually iron oxide from the mold. "Checks" are small cracks due to faulty pressing in the mold or to temperature shock encountered on the lehring screen or to other causes. "Shear mark" is a crease formed during cutting off of the hot gob of glass, prior to blowing or pressing. "Lap" is a fold formed during the loading of or pressing in the mold. "Chill marks" may appear as a wrinkled, wavy surface when the glass has been cooled very quickly.

Thin areas in the walls or thick bottoms are usually due to faulty blowing and can be prevented by having the glass at proper temperature and viscosity when blown and by operating the container-forming machine at proper speed and air pressure.

Types of Glass Containers and Closures. Glass containers for foods are of many designs, shapes, and sizes. Perhaps the simplest is the common jelly glass for home use in which the jelly or jam is sealed (though ineffectively at best) by a layer of melted paraffin. Jelly glasses for home use

with screw tops with inner cut rubber seals are now available. Similar jars are used commercially for pickles, jams, jellies, and other products.

The well-known Kerr Mason jar for home use is closed with a metal disk carrying a circle of rubber composition that rests on the rim of the jar and a separate screw top to hold the disk tightly against the rim of the jar. In the older type of Ball Mason jar the seal is made by a rubber ring and screw top. Another popular jar for home use has a separate glass top between which and the rim of the jar is a rubber ring. The glass cap is held tightly in place by a stiff wire bail.

Another common closure consists of screw cap carrying an inner liner (cardboard heavily coated with an impervious plastic or with wax). It is commonly used on mayonnaise jars.

A widely used jar closure for commercial use is the White Vapor Vacuum cap. It is applied to the jar as the head space is filled with a jet of steam in much the same manner as cans are steam-flow- or steam-vac-sealed. It is a press-on type of lid, the seal being made by a rubber-gasket composition ring that fits around the side of the jar. The gasket material must have considerable give and resiliency and must not collapse or unduly soften during sterilization or become hard and porous on the grocer's shelf.

It has the advantage that it may be pressed into place by hand to reseal the jar after opening. Another commercially used press-on cap is the Anchor Steriseal tapered finish press-on cap. The Owens Illinois Glass Company cap, which is widely used commercially, is known as the Vapak press-on cap. The seal is made by a rubber composition ring that is locked in place in the cap and which fits below a slight bead around the jar. The bead gives greater resistance to "blow out," during processing, and a better reseal after opening the jar. Also, it is designed so that the metal of the cap does not rest on the rim of the jar and therefore there is no danger of marring the enamel on the inside of the cap during sealing.

The most widely used closure for beverage bottles is the Crown cap, familiar to all readers as a closure for bottled soda water, fruit juice, and beer. It is also used to a lesser extent for horseradish, oyster-cocktail, and similar small widemouth jars. It consists of an impervious paper or metal-foil disk that rests against the rim of the bottle, a backing of cork or paper, and an outer fluted metal disk of heavy tin plate, which is crimped tightly over the rim of the bottle by a simple cuplike plunger.

Bottles for fortified dessert wines in California are closed with enameled metal screw caps lined with cardboard covered with plastic or wax. Dry-wine (table-wine) bottles are usually closed with high-quality corks.

Recently an aluminum-foil, "roll-on" cap has come into general use as a closure for catsup bottles. It is purchased as a blank cap (without threads), slightly larger in diameter than the top of the bottle. After the bottle is filled the cap is dropped over the top of the bottle and the foil is compressed

into the threads on the neck of the bottle by a special machine that operates at great speed. The lid may be unscrewed by the consumer to open the bottle and is then used as a reseal.

Sizes. The sizes and shapes of glass containers are numerous and varied. Those used for home canning are usually of quart or pint capacity, although jars of half-pint size are available. Widemouthed jars for coffee, mayonnaise, and pickles may be as large as 1 gal. Screw-top widemouthed jars of quart, pint, 12-ounce, and half-pint (8-oz.) size are in common use for various products. For horse-radish, mustard for home use, etc., 4-oz. screw-top jars are common.

Bottles for food products range in size and shape from the 5-gal. carboys used for wine to the 4-oz. bottle used for individual servings of juice or wine. The most common closure is the Crown cap, although the White Vapor Vacuum cap is also in common use for juice bottles. Wine bottles are usually of ⅕-gal. capacity, rather than a full quart, and of one-half this capacity ("short" pints). The 12-oz. bottle is common for beer and some soft drinks, and the usual soda-water bottle holds 6 or 7 oz. of liquid. A detailed chart of sizes, dimensions, and weights of glass containers for food products may be had from the Glass Container Manufacturers' Institute of New York.

Glass-container Uses and Statistics. According to the Glass Container Manufacturers' Institute, approximately 7,300 million new jars and bottles were used for food products in 1954, and approximately 4,300 million for beer, wine, liquors, and soft drinks. About 42 per cent of all glass containers made in 1954 were used for foods. In addition, many used milk, soda-water, and beer bottles were employed. A milk bottle is used an average of 30 times, soda water bottles 20 times, and beer bottles 18 times, before being discarded or broken. It is estimated that 174 bottles of soft drinks were consumed per capita in 1954, or about 28,240 million total for the United States. About 70 per cent of all processed baby foods are packed in glass containers, the remainder in tin. Tin is the more common container for baby foods in the Pacific Coast states, and glass in the Eastern states. The present ratio of glass containers to the tin for beer is about 70 of glass to 30 of tin. Recently tin containers have been used on a limited scale for soft drinks, and this use may increase.

Instant (powdered) coffee is usually packed in glass containers. Jellies, jams, preserves, fruit juices (other than frozen), catsup, pickles, peanut butter, salad dressings, mayonnaise, green olives, and honey, in addition to soda waters, beer, wines, liquors, and milk, mentioned previously, are packed in glass. Tin is also used for certain of these products, notably beer and baby foods.

It is a common belief that glass containers suffer considerable breakage during shipment and handling in commerce. However, according to the

Glass Container Manufacturers' Institute, a survey made by the railroads and the Fiber Box Association showed that the average freight-damage claim on foods and beverages in glass was about \$10 per car, compared with \$44 per car for fruits and vegetables in tin and \$55 per car for juices in tin.

The Institute estimates that when there is taken into account the many trips made by milk, soft-drink, and beer bottles and the many nonfood products such as chemicals, medicines, etc., that are packed in glass, the total number of units of glass-packed materials of all kinds was about 73 billion in the United States in 1954, or about 454 per capita.

REFERENCES

AMERICAN IRON AND STEEL INSTITUTE: "Steel Products Manual—Tin Mill Products," New York, 1949.

BATELLE MEMORIAL INSTITUTE STAFF: Tin plate and tin cans in the United States, *Intern. Tin Research Develop. Council, London, Bull.* 4, 1936.

BOHART, G. S.: Special enamel for corn cans, *Natl. Canners Assoc. Circ.* 10-L, 1924.

BRIGHTON, K. W., PILCHER, R. W., and LUECK, R. H.: Metal cans of the future, *Food Technol.*, **8**(9), 424–430, 1954.

"The Canned Food Reference Manual," American Can Co., New York, 1949.

"Controlling the Top Double Seam," Research Department, Continental Can Co., 1952. A bulletin.

"The Double Seam for Sanitary Cans," Research Department, American Can Co., New York, 1950.

FLUGGE, S. L.: Can linings, *Continental Can Co., Research Dept., Bull.* 23, 1951.

Glass Container Manufacturers' Institute: The history of glass containers, New York, 1955.

HARTWELL, R. R.: "Choice of Containers for Various Products," American Can Co., Research and Technical Dept., New York, 1956.

———: Corrosion factors related to the use of tin plate for food containers, *Food Technol.*, **5**(10), 402–408, October, 1951. See also "Advances in Food Research," vol. 3, pp. 328–378, Academic Press, Inc., New York, 1951.

HOARE, W. E.: "Tin Plate Handbook," Tin Research Institute, London, 1950.

LUECK, R. H.: Metal container changes in tin conservation, *Proc. Inst. Food Technologists*, 1942, pp. 128–144.

MACNAUGHTON, D. J., and HEDGES, E. S.: Tin plate and canning in Great Britain, *Intern. Tin Research Develop. Council Bull.* 1, 1935.

MARTIN, E. D.: Significance of continuous production methods in the manufacture of tin plate, *Food Technol.*, **5**(10), 398–402, October, 1951.

MCGRANAHAN, C. L.: Production of hot and cold rolled steel strip and sheets, *Steel*, **20**, 104, 1949.

MENEILLY, R. M.: Progress in the tin plate industry, *Food Technol.*, **5**(10), 385–398, October, 1951.

MOREY, G. W.: "The Properties of Glass," 2d ed., Reinhold Publishing Corporation, New York, 1954.

MUNNS, J. J.: "Differential Coated Electrolytic Tin Plate," American Iron and Steel Institute, New York, 1951.

National Canners Association Research Staff: Canned food containers, with special reference to influence of the steel base on resistance to corrosion, *Natl. Canners Assoc., Research Lab., Bull.* 22-L, 1923.

PHILLIPS, C. J.: "Glass the Miracle Maker," Pitman Publishing Corporation, New York, 1941.

ROGERS, A.: "Industrial Chemistry," vol. 1, chap. 12, D. Van Nostrand Company, Inc., Princeton, N. J., 1926. Glass-container manufacture.

STEVENSON, A. E.: Effect of progress in tin plate manufacture on the use of tin plate for canned foods, *Food Technol.*, **5**(10), 408–412, October, 1951.

TOOLEY, FAY V.: "Handbook of Glass Manufacturing," Ogden Publishing Co., New York, 1953.

VAN VLETT, H. S.: Engineering the tin can, *Mech. Eng.*, **70**(4), 1948.

WRIGHT, F. H.: Glass containers in food manufacture, *Western Canner and Packer*, **48**(13), 20–31, December, 1956.

CHAPTER 3

WASHING, BLANCHING, AND PEELING FRUITS AND VEGETABLES

Washing, blanching, and peeling fruits and vegetables for canning, freezing, or drying may be conveniently considered together, since in many instances these operations are conducted simultaneously.

WASHING FRUITS AND VEGETABLES

Water is used for five purposes in the cannery: (1) for the generation of the steam used in sterilizing, (2) for lye peeling, washing, and other preliminary treatment of the raw materials, (3) for the preparation of brine and sirup, (4) for washing the floors, machinery, and cans, and (5) for cooling the canned product.

Soaking. Fruits or vegetables may be washed with water in three different ways: soaking, washing by agitation, and sprays. Soaking is not in itself an effective means of removing dirt but is useful as a preliminary treatment to washing by sprays or by agitation. It is especially desirable for tomatoes because it softens the adhering soil and renders washing by sprays more effective. Tomatoes are usually dumped into a soaker wash tank.

Hot water is a more effective soaking agent than cold water. It is essential that the water be abundant and changed frequently; otherwise the soaking vat may serve as a source of contamination rather than as a means of cleansing. Wash water is often continuously chlorinated.

Washing by Agitating in Water. If the fruits or vegetables are agitated in water, the efficiency of the soaking process is greatly enhanced. A very simple form of agitating washer is that used in some factories for the washing of apples for cider manufacture, in which the apples are conveyed through a current of rapidly running water in a wooden flume.

Compressed air is sometimes used to agitate water in tanks in which the fruit or vegetables are to be washed, as in one method of washing spinach, or it may also be agitated or circulated by means of a pump. Some soaking vats are equipped with a propeller, which may be in contact with the product, in which case the propeller should move slowly to avoid bruising; or it may be enclosed in a small heavily screened cage at one side of the tank.

The rotary washer used in the lye peeling of peaches is very effective. This consists of a rotary drum or a series of several drums, each of which is equipped with an inner helical conveyer. The drums rotate in tanks of water in which the water is changed continuously or frequently. Such a washing system has been used for lye-peeled peaches. The spiral carries the fruit progressively through the different washing tanks, the first of which is contaminated with a small amount of lye from the lye-peeling tank, while

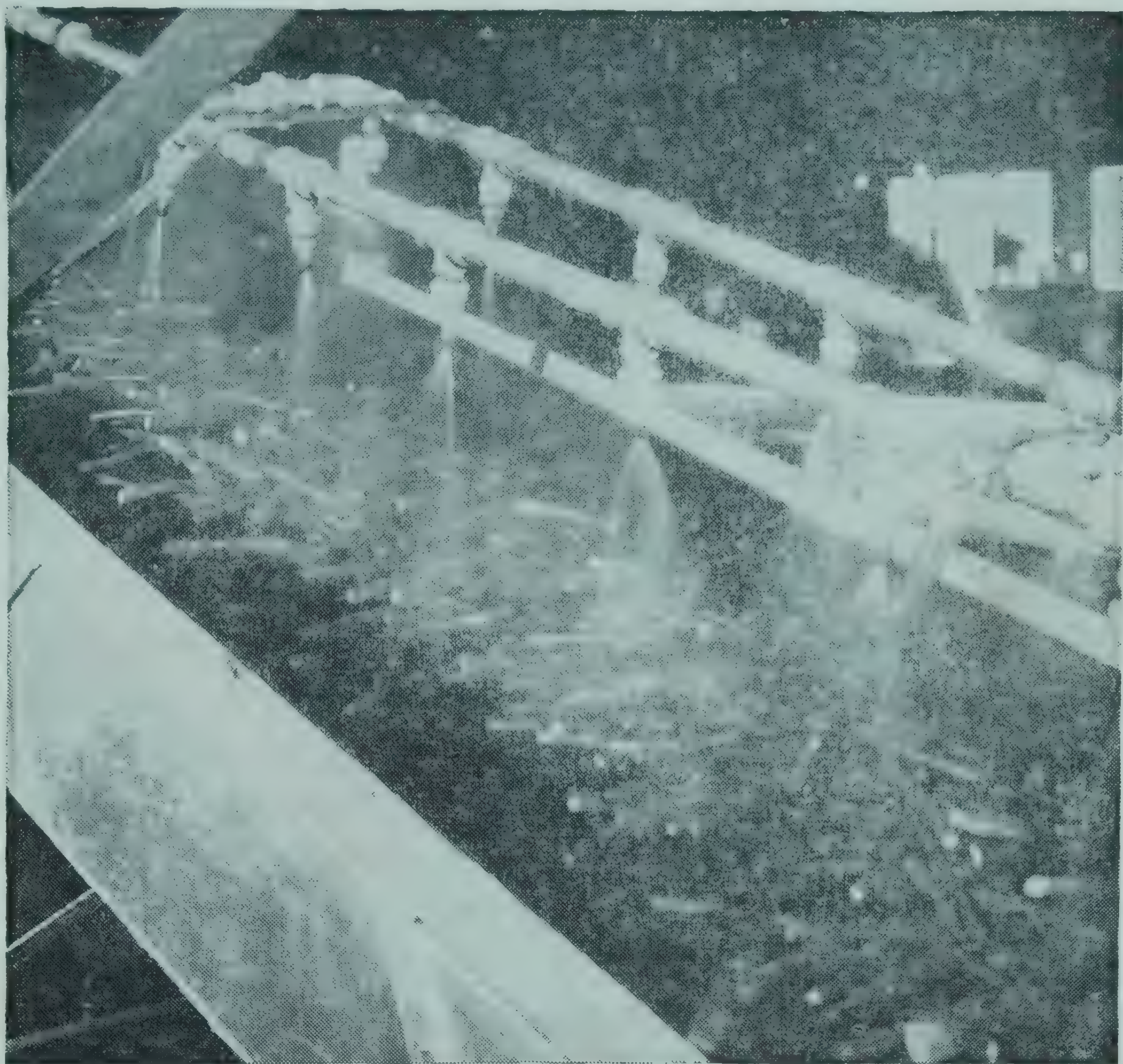


FIG. 9. Spray washer or cooler for asparagus. Useful for other products. (*Food Machinery Corp.*)

the last two tanks are filled with hot and cold water, respectively. This washing device is also used in lye dipping and rinsing of prunes for drying. It has great capacity, does not bruise the fruit badly, and is economical of water. It is not, however, so effective or economical of water as the spray system. In the washing of some vegetables and oranges a detergent is added to improve cleansing action.

Washing by Sprays. Washing of fruit and vegetables by means of sprays of water is by far the most satisfactory method. Products that are heavily contaminated with soil or other objectionable material should first be soaked thoroughly to loosen adhering soil before washing under sprays.

The efficiency of a spray of water for washing depends upon the pressure of the water, upon its volume, and also upon the distance of the spray

nozzle from the product to be washed. The spray in which a small volume of water under heavy pressure is used is very much more effective than the one in which a large volume of water under low pressure is employed.

The distance of the nozzle from the product to be washed very greatly affects the efficiency of the spray. Too little attention has been given to this very important detail in some spray-washing machines.

Most spray washers consist of pipes that are fitted with hack-sawed openings, but for pressures of water in excess of 20 lb. per sq. in. it is advisable that adjustable nozzles be used to prevent unevenness and to direct the sprays in the desired channels. The sprays are effective only if the water touches all parts of the surface of the product. One means of attaining this object is to place sprays above and below a traveling woven wire-cloth conveyer. The same effect can be obtained by causing the product to roll during the spraying process. The most effective means of agitating the product under the spray is the revolving spray-washing machine used on tomatoes and roots. This consists of a slightly inclined perforated drum fitted on the inside with spirals or with corrugations. This type of washer is also used effectively in the washing of spinach.

The effectiveness of the rotary washer depends upon the speed with which the product passes through the washer, the volume of water used, the temperature of the water, the distance of the sprays from the product, and the depth of the product in the washer. Many washers are overloaded with such products as tomatoes, with the result that much of the material does not receive the full force of the sprays.

In many tomato-products plants a combination of roller conveyer and sprays is used. The conveyer is about 2½ ft. wide and is made up of bronze or stainless-steel tubes about 3 in. in diameter placed crosswise and moved by an endless link chain. As the conveyer travels, the tubes revolve, turning the tomatoes over and over and exposing them on all sides to the sprays. Two sets of sprays are used, one under very heavy pressure, up to 400 lb. per sq. in., and one under medium pressure. Beyond the sprays the roller conveyer serves as a very effective sorting belt. This conveyer washer is also suitable for potatoes and some other products. It is also used for sorting of walnuts and certain fresh fruits (Figure 18).

SCALDING AND BLANCHING

Most vegetables are heated in water or in live steam before canning, this treatment being known among canners as "blanching." It cleanses the product and decreases its volume so that a well-filled can is obtained; in some cases it removes disagreeable odors or flavors; and with some vegetables it removes slime-forming substances. It may or may not aid in retention of the green color of the vegetables, depending upon the vegetable, the

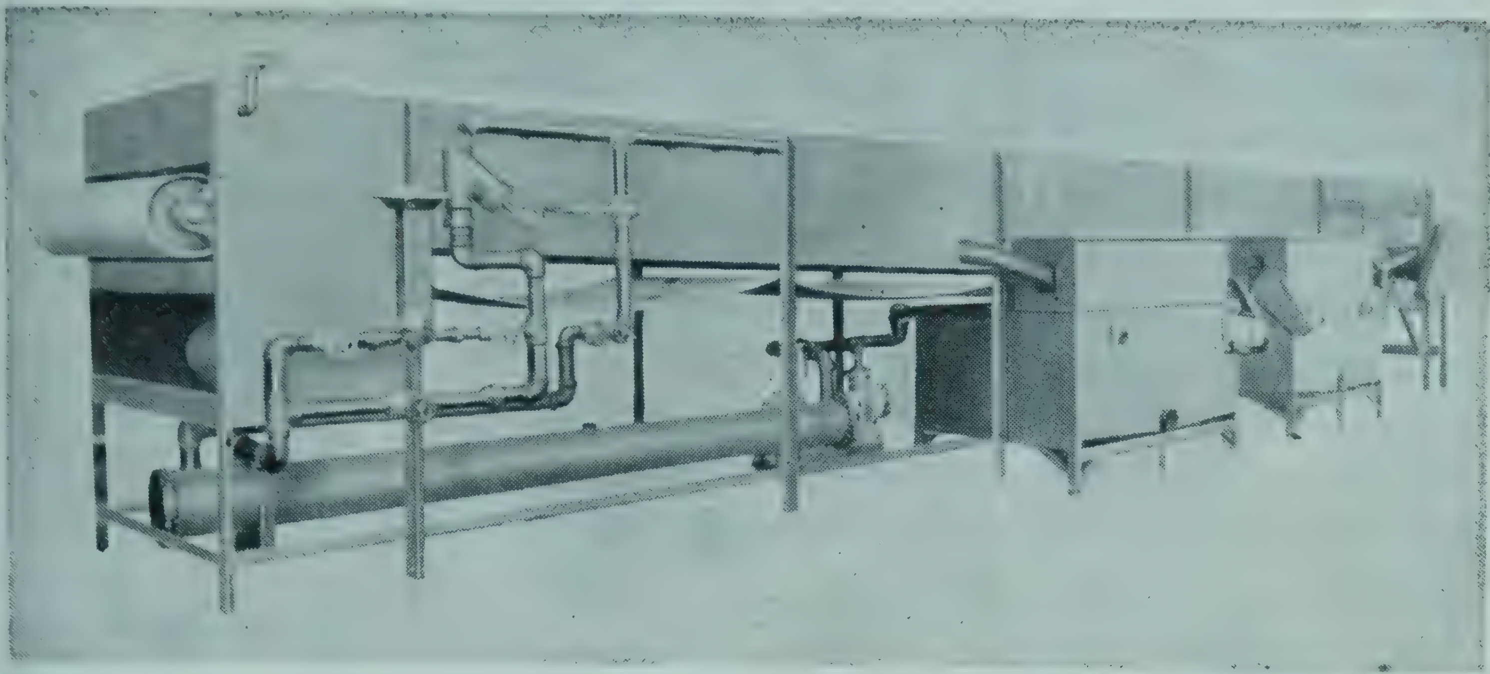


FIG. 10. Cup-down clingstone peach peeler. Used for applying solution and water. (*Food Machinery Corp.*)

temperature used in blanching, and the method of preservation used after blanching.

The procedure and equipment will vary with the vegetable. At present spinach is passed by conveyer through a long, covered metal tank containing water held at about 170°F. by means of automatic temperature regulators that control steam jets. This procedure is known as the Thomas process and formerly was operated under the Thomas patent, at present held by the California Packing Corporation. The patent has now expired. At the boiling point blanching of spinach results in loss of the green color, i.e., in decomposition of the chlorophyll to phaeophytin of a yellowish-green color. Blanched at 170°F., it retains its natural green color to a remarkable extent, even when heated to 250°F. during subsequent sterilization. Why the lower temperature fixes the color has been a mystery. One hypothesis has been that oxygen in the leaves oxidizes the chlorophyll at the boiling point and does not do so at 170°F., the gas also being given an opportunity at the lower temperature to escape from the tissues so that oxidation does not occur during subsequent sterilization. In experiments conducted by the author in 1924, it was found that subjecting spinach leaves to a high vacuum for several minutes under water—to remove gases from the tissues—greatly improved the color attained in blanching. Another hypothesis is that blanching at the lower temperature leaches considerable acid from the vegetable so that there is less hydrolysis of the chlorophyll to phaeophytin during subsequent sterilization. The fact that spinach leaves or other green vegetable impregnated with dilute sodium bicarbonate or buffered to neutrality or faint alkalinity in other ways retain their green color remarkably well is a point in favor of the phaeophytin hypothesis. Another theory is that at the lower temperature the enzyme chlorophyllase remains active for a few minutes and converts

chlorophyll to a phyllin which retains a green color. Weast and Mackinney have studied this problem (see references at the end of the chapter). One objection to the blanching of spinach at 170°F. is the greater difficulty encountered in filling the can so that it will contain the minimum legal drained weight after sterilizing.

Peas and string beans for canning are generally carried through hot water, usually boiling, during blanching. The severity of blanching should be regulated according to the maturity and tenderness of the vegetable by varying the length of the blanching period or the temperature of the water. Hard water that is high in calcium or magnesium salts will cause hardening and toughening of peas blanched in it, probably owing to reaction with pectic substances. Asparagus formerly was placed in rattan baskets that were conveyed through long vats of water at, or slightly below, boiling. The blanching of asparagus is now done in live steam at most canneries.

In blanching green vegetables for freezing storage, H. C. Diehl of the U.S.D.A. found that it is necessary to heat sufficiently to destroy the catalase enzyme in order that the frozen vegetables will not develop a hay-like odor and flavor in storage. Joslyn and Marsh of the Fruit Products Laboratory of the University of California have shown that blanching should be sufficient to destroy not only catalase but also peroxidase; i.e., the blanching should be more severe than that recommended by some authorities. Unblanched and underblanched green vegetables develop a grayish-green color as well as disagreeable odor and flavor during storage.

Corn, cream-style for canning, is not blanched on the cob but it is given a precook before canning; but that for freezing is blanched on the cob. Pumpkin is cut in large pieces and is then cooked in the shell until soft, the object being to permit separation of the flesh and shell mechanically before canning.

Tomatoes are blanched in steam or boiling water a short time to crack and loosen the skins. Sweet potatoes and beets are usually heated in steam or in steam under pressure in order to facilitate peeling.

Pimientos are usually roasted in a gas flame or red-hot metal drum instead of being blanched in water or steam, as very severe heat-treatment is required to loosen the skins.

Peaches are often blanched after lye peeling in order to remove the last traces of lye and to inactivate the oxidase responsible for browning. Other common canning fruits are not blanched.

Prunes that are being prepared for drying are dipped about 30 sec. in dilute lye solution (0.5 to 1.5 per cent sodium hydroxide) to crack the skins and thus facilitate drying. Some Thompson seedless grapes are treated in similar fashion.

Magoon and Culpepper concluded from their investigation on blanching that steam is preferable to boiling water as a blanching agent, as it extracts

less of the valuable food materials. However, Adam and Horner in England and Wagner et al. at the University of Wisconsin have found that losses in steam blanching are also severe. However, steaming destroys most of the green color in spinach; i.e., it so affects it that it bleaches to a yellowish green during sterilization in the can.

The subject of blanching is a very important one, as well as one that is imperfectly understood and in need of much research. It is discussed further in Chapter 10, Canning of Vegetables.

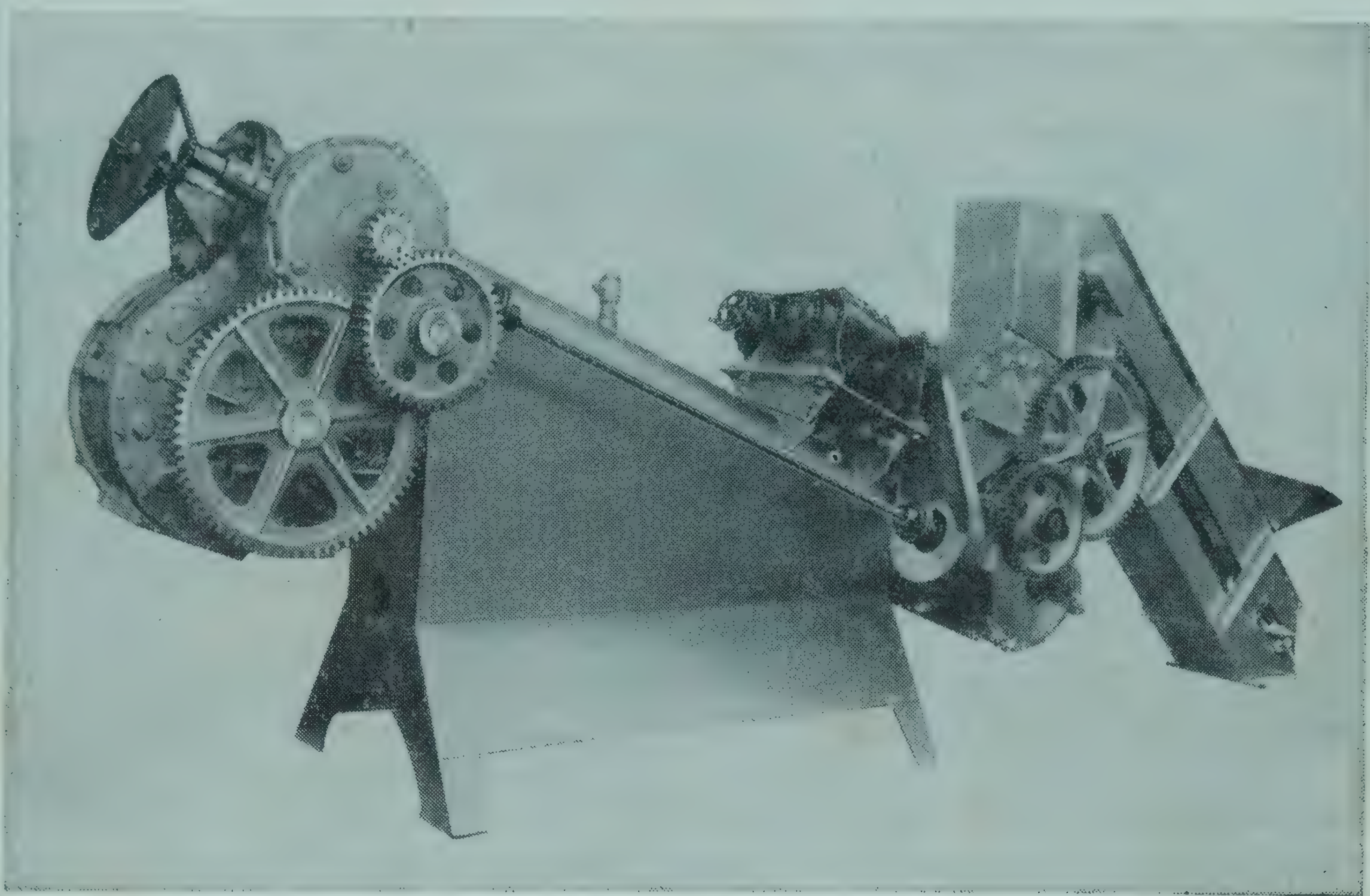


FIG. 11. Continuous high-pressure steam peeler. (*Food Machinery Corp.*)

PEELING FRUITS AND VEGETABLES FOR CANNING

The quality of certain canned fruits and vegetables depends in large measure upon the care taken in peeling.

Hand Peeling. During the first years of the fruit-canning industry in California, peaches were peeled by hand. At the present time commercial canners do not peel the fruit in this manner but use instead the lye-peeling system.

The knife formerly used for the hand peeling of peaches has a curved blade with an adjustable guide which permits regulation of the depth of peeling. The objection to the hand peeling of peaches is that it is very much more costly than lye peeling and is more wasteful of fruit. The hand peeling of vegetables of certain varieties is sometimes used in conjunction with various other preliminary treatments that are discussed later.

Pears for canning were until recently peeled by hand, as previously

described; the fruit was cut in half, and the stems, calyxes, and cores were removed. Apricots in most California plants are cut in half by small machines fed individually by women operators, although some apricots for canning are still pitted by hand. Satisfactory mechanical machines are now available that peel, core, and cut pears in half for canning. All canneries use them. All clingstone peaches canned in California are halved and pitted by machine.

Use of Heat in the Peeling of Fruits and Vegetables. Some varieties of peaches may be peeled by placing the halved or whole fruit on trays in a steam box for 2 or 3 min. or by immersing the halved fruit in boiling water

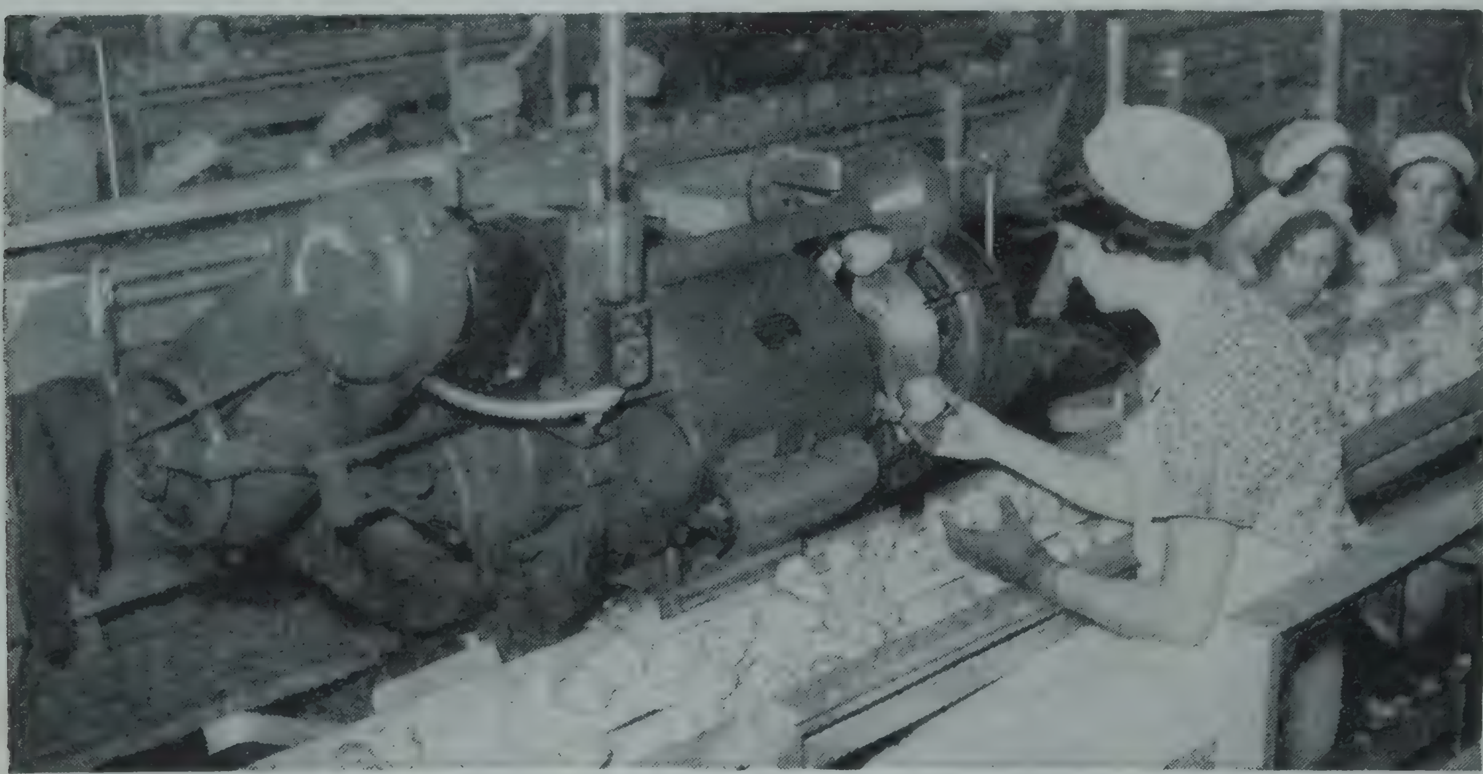


FIG. 12. Pear coring, peeling, and trimming machine. (*Food Machinery Corp.*)

for a short time. This treatment loosens the skins so that they may be easily slipped from the fruit with the hands.

Tomatoes are blanched in steam or in boiling water, and then immersed or sprayed with cold water to cool the fruit and to loosen the skins. After blanching and cooling, the tomatoes are easily peeled by hand. Boiling water is probably more desirable than steam as a blanching agent for tomatoes for the reason that it heats them uniformly and cleanses them in addition to loosening the skins. The time for immersion in boiling water is approximately 30 to 60 sec. Tomatoes have been peeled by treatment in boiling lye solution followed by high-temperature steam. This method is used for pimientoes for canning.

Sweet potatoes are steamed under pressure to soften the skin and are then peeled by hand or are lye-peeled without preliminary steaming.

Beets are blanched in boiling water or in steam under pressure until the skin may be separated from the flesh easily. The blanched or parboiled beets are peeled by hand. Recently the peeling of carrots, beets, and pota-

toes as well as some other vegetables and apples has been done commercially by heating in steam under pressure to a very high temperature for a few seconds and then releasing the pressure suddenly. This is done in continuous as well as batch peelers.

Pimientos are canned in large quantities in southern California and in Georgia. Four different methods of peeling are in use. In one process the pimientos are passed through a revolving steel cylinder that is heated by a direct gas flame. The pimientos are roasted, and the peels may be easily removed from the roasted product by hand or heavy sprays.

The second process consists in passing the pimientos through a bath of cottonseed oil at about 400°F. This accomplishes the same purpose as the roasting process.

The third process of peeling pimientos is with a dilute boiling lye solution in the same manner as described for the lye peeling of peaches. This is the least satisfactory method and is now seldom used. The fourth method is that of heating a short time to a high temperature, as described for beets, carrots, and apples, usually after treatment in strong lye solution.

Mechanical Peeling. Apples are peeled in machines that remove the peeling, core the fruit, and, if desired, cut it in circular slices.

Root vegetables, such as carrots, turnips, parsnips, etc., can be peeled in a mechanical peeler consisting of an upright cylinder provided in the bottom with a rapidly revolving disk, which in addition to its rotary motion undergoes an undulatory movement. The inner walls of the cylinder and the upper surface of the disk are coated with an abrasive material, such as carborundum. As the disk revolves, water is sprayed into the peeler, washing away the grated peelings and facilitating the peeling process. Pears are now peeled and cored by machine (Figure 12). However, lye peeling is used for carrots and potatoes to be dehydrated.

Lye Peeling. Lye peeling was probably first used commercially in the production of hominy, when the corn was peeled with lye consisting of the leachings from wood ashes. Corn was boiled in this dilute lye solution until the skins could be slipped from the kernels with the fingers and the skins removed by washing the lye-treated corn in running water. At the present time, hominy is made by boiling corn in dilute sodium hydroxide solution, followed by removal of the skins in revolving cylinders and running water. Usually a small amount of sodium hydroxide remains in the finished product. Lye peeling is used on peaches, sweet potatoes, apricots, and carrots.

The application of lye peeling to the preparation of fruits for canning is more recent. The first patent granted for the lye treatment of fruits was in 1901 for a process of dipping prunes in lye to facilitate drying. In this process the lye treatment is not prolonged sufficiently to peel the fruit but merely checks the skins.

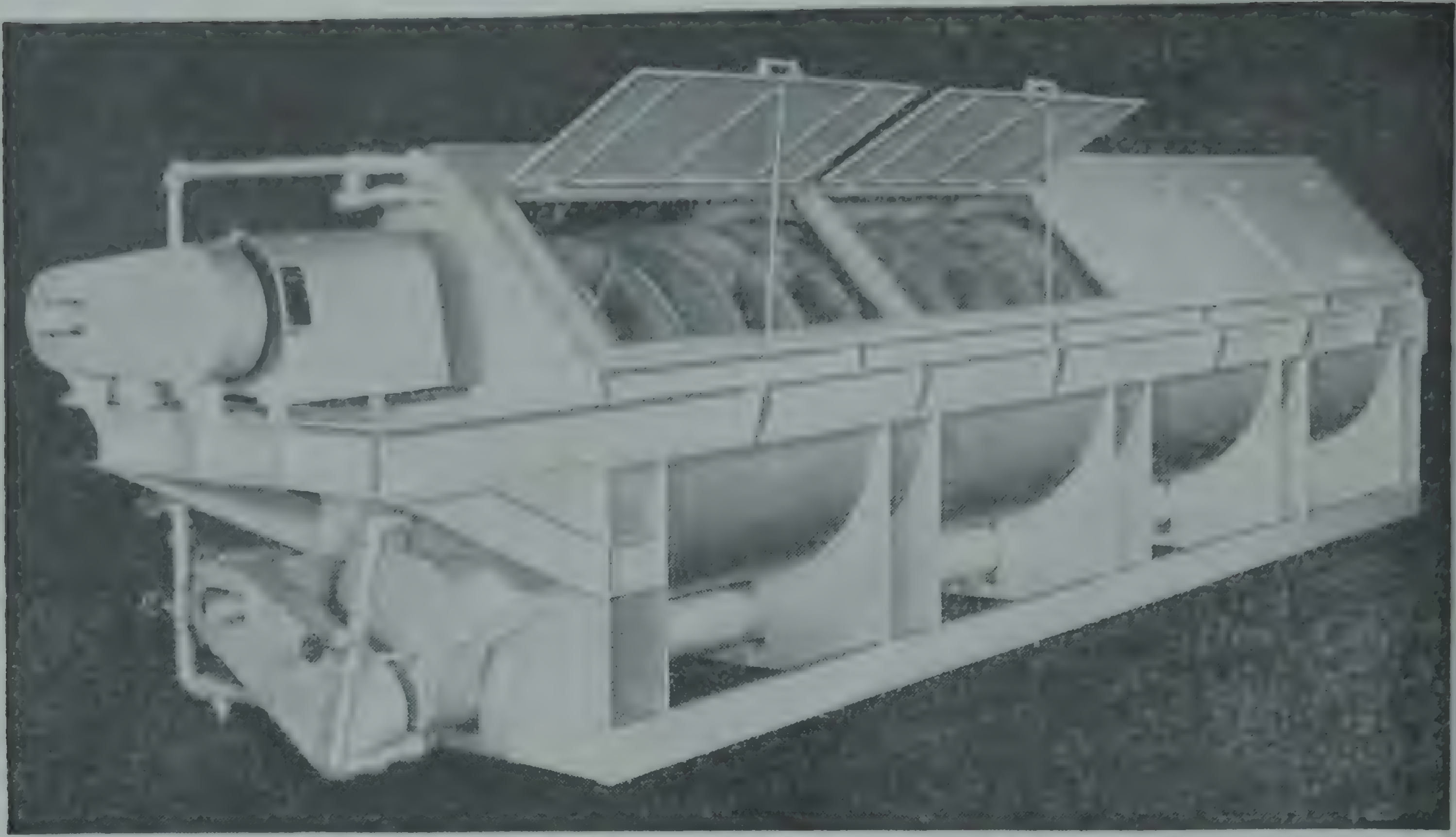


FIG. 13. Sani-Flow blancher. Model 16, for peas and other products. (*Food Machinery Corp.*)

The first patent for the lye peeling of peaches and other fruits was granted in 1902. Experiments by M. E. Jaffa, of the University of California, and others have proved that lye-peeled fruit contains no free alkali, because the small amount of lye remaining in the fruit after washing is neutralized by the acidity of the fruit.

Advantages. The advantages of lye peeling as compared to the hand peeling of peaches are (1) reduced cost of peeling, (2) more rapid handling of the fruit, and (3) less loss of fruit by peeling.

Action of Lye. A boiling dilute lye solution causes the separation of the outer skin of the peach from the flesh beneath the epidermal layer, which is insoluble in the dilute lye. The middle lamella of cells consists of pectinous substances that are very soluble in the lye. The parenchyma cells of the peach are large and more resistant to the lye than the cells immediately beneath the epidermis. The vascular bundles throughout the tissues of the fruit are resistant to the lye solution. If the lye-peeling process is carried out satisfactorily, the pectinous substances of the middle lamella of cells beneath the skin will be dissolved and the parenchyma cells will be uninjured. If the lye solution is applied for too long a time or is too concentrated, the surface of the lye-peeled peach will be rough and pitted because of the action of the lye on the flesh.

In the lye peeling of sweet potatoes the action of the lye is upon the cutin. The epidermis of the sweet potato is made up of cork cells, which are insoluble in the lye solution. Because of the resistance of the epidermis, the treatment is applied for a longer time than in the peeling of peaches, e.g., 6 to 8 min. as compared with ½ to 2 min. for peaches.

Forms of Lye Used for Peeling. Sodium hydroxide is the most common lye used in the peeling of fruits. A mixture of sodium carbonate and sodium hydroxide may also be used, although the action of the carbonate is much less vigorous than the action of the hydroxide. However, the presence of the carbonate makes it much less difficult to wash the lye from the fruit, according to suppliers. The sodium carbonate–sodium hydroxide mixture is sold as "canners' alkali."

Convenient forms of the sodium hydroxide are the granular and the flake, either of which would contain at least 95 per cent sodium hydroxide. Most canneries and olive plants now purchase in tank carlots a solution containing about 50 per cent of NaOH. The manufacturers of sodium hydroxide report its strength to the canner as "per cent sodium oxide" (Na_2O). The relation between per cent Na_2O and per cent NaOH (sodium hydroxide) is shown in Table 2.

TABLE 2. RELATION OF SODIUM OXIDE TO SODIUM HYDROXIDE CONTENT OF COMMERCIAL SODIUM HYDROXIDE

Per cent sodium hydroxide, NaOH	*Per cent sodium oxide,* Na_2O
50	38.75
60	46.50
70	54.25
75	58.12
80	62.00
85	65.87
90	69.75
95	73.62
98	75.95
100	77.50

It is unfortunate that this system of reporting the strength of canners' lye has come into commercial usage, because sodium hydroxide, and not sodium oxide, is the active agent.

Lye-peeling Machines. Several forms of lye-peeling machines are in commercial use. The Dunkley lye peeler consists of a long, elevated rectangular sheet-metal box through which a wide endless woven-wire conveyer carries the halved peaches or other raw material. As the product enters the peeler it is subject to sprays of hot water. The fruit then passes through sprays of hot lye solution applied to it from beneath and above the screen in the more common machine. Freestone peaches and clings pitted by "twist" pitter travel with cut surface downward, and the hot lye solution is applied only to the upper, skin surface in order not to damage the flesh in the pit cavity. While the fruit is not agitated, all portions of the surface are thoroughly acted upon by the hot lye solution. The lye and hot water are held in tanks beneath the peeling chamber and are circulated by means of pumps. After passing through the lye sprays, the fruit is subjected to

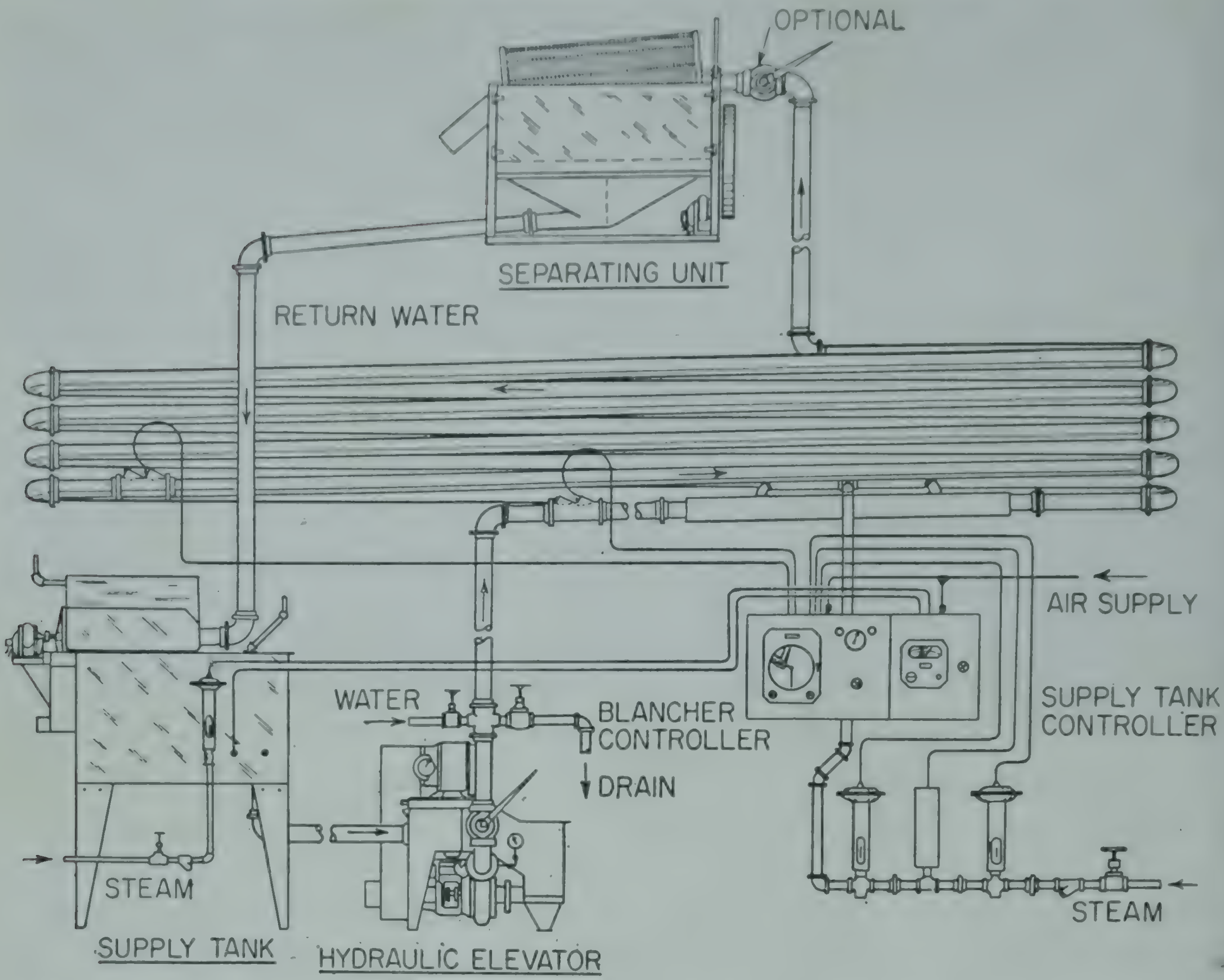


FIG. 14. Hydraulic pressure blancher for peas, corn, beans, and other products that can be pumped. Also known as tubular blancher. (*Scott Viner Co., Columbus, Ohio.*)

sprays of water. The water used in the first set of sprays is circulated by means of a pump and is used repeatedly, but the final washing of the fruit is accomplished by sprays of fresh cold water.

The Kyle peeling machines make use of agitation of the lye-treated fruit in water as a means of removing the lye and skins. A revolving drum first carries the halved peaches through a tank of boiling dilute lye solution, and then through a tank of running water. In recent years, however, the tank of water has been replaced with, or is followed by, sprays of water in some plants, as the Dunkley patent on the use of sprays has expired.

In most canneries the lye-peeled fruit is passed through a tank of hot water (at 140 to 180°F.) after washing, to remove the last traces of lye and supposedly to inactivate the oxidase in the surface of the fruit. Oxidase is an enzyme that induces browning of the peach flesh and, as shown by Quin and Cruess, is inactivated in peach tissue at about 180°F. Therefore heating at 140°F. affects it but little, and the principal beneficial effect of water at the lower temperature is removal of traces of lye. Quin and Cruess found that browning of lye-peeled peaches between the time of peeling and placing the fruit in the cans can be completely prevented by immersing the peeled

fruit in dilute hydrochloric acid for a few seconds. The inhibiting action of this acid is due to both the hydrogen ion and the chloride ion. The trace of acid is removed later at the canning table by rinsing in water. The hydrochloric acid forms harmless sodium chloride (ordinary salt) with the traces of residual lye on the fruit and inactivates the oxidase. Citric acid solution, about 0.5 per cent, can be used instead of the hydrochloric, but is not quite so effective. It was found in these experiments that the natural pH value of the flesh of canning peaches is usually 3.8 to 4.0, whereas that in the pit cavities ("cups") of the lye-peeled peaches after washing is often above pH 7.0 (slightly alkaline) and of the outer surface of the peach often above pH 4.5. At these relatively high pH values, darkening is extremely rapid, as oxidase action is favored by low acidity or slight alkalinity. For this reason Quin and Cruess recommend that the fruit be given a dilute acid bath or spray following washing after lye peeling, in cases where browning is serious. This problem will be discussed further in Chapter 8.

Concentration of Lye Solution. The usual concentration of the lye solution is from 1.5 to 2 per cent sodium hydroxide for fruits, but it may be stronger for green fruit and somewhat weaker for ripe fruit of varieties that are easily lye-peeled. For carrots and potatoes it is usually 10 to 15 per cent. It is varied materially according to variety and maturity. The temperature should be maintained at, or within a few degrees of, the boiling point. Heating the fruit in hot water or steam before it enters the lye solution greatly improves the peeling action of the lye. This is usually done in the Dunkley peeler.

In most canneries no attempt is made to control the concentration by chemical analysis of the peeling solution, although in a number of others samples of the solution from the peeling tank are titrated frequently with standard acid solution, and the solution is adjusted as required. The fruit rather rapidly neutralizes the lye, and much of the solution is carried out of the vat mechanically by the fruit. Water must be added to maintain the volume constant. Automatic control devices dependent on conductivity of the liquid are also in use.

The concentration of the peeling solution can also be determined quickly and accurately by means of an electrical conductivity instrument, constructed for use with ordinary 110- or 220-volt alternating current. There are also indicating conductivity instruments that can be attached to simple iron electrodes, such as those of a spark plug, inserted in the boiling lye solution. The instrument can be calibrated by titration of several lye solutions. The operator can then at all times determine at a glance the concentration of the lye solution in the peeling tank. Fortunately, the hydroxide ion is a very much better conductor than the negative ions of organic acids; thus the conductivity is but little affected by salts of sodium formed by neutralization of the lye by acids of the fruit.

In some canneries strong, or in some cases saturated, lye solution is added to the lye-peeling solution to maintain the desired concentration; in others flake hydroxide is added directly. Some canners have used the solid fused NaOH in steel drums, as follows: The drum is placed on end above the tank, and steam is admitted through a hole in the bottom of the drum. The condensed hot water formed slowly dissolves the "caustic" (NaOH), and the saturated solution trickles in a small stream into the tank. Strong NaOH solution in tank carlots is now supplied to canneries by chemical manufacturers.

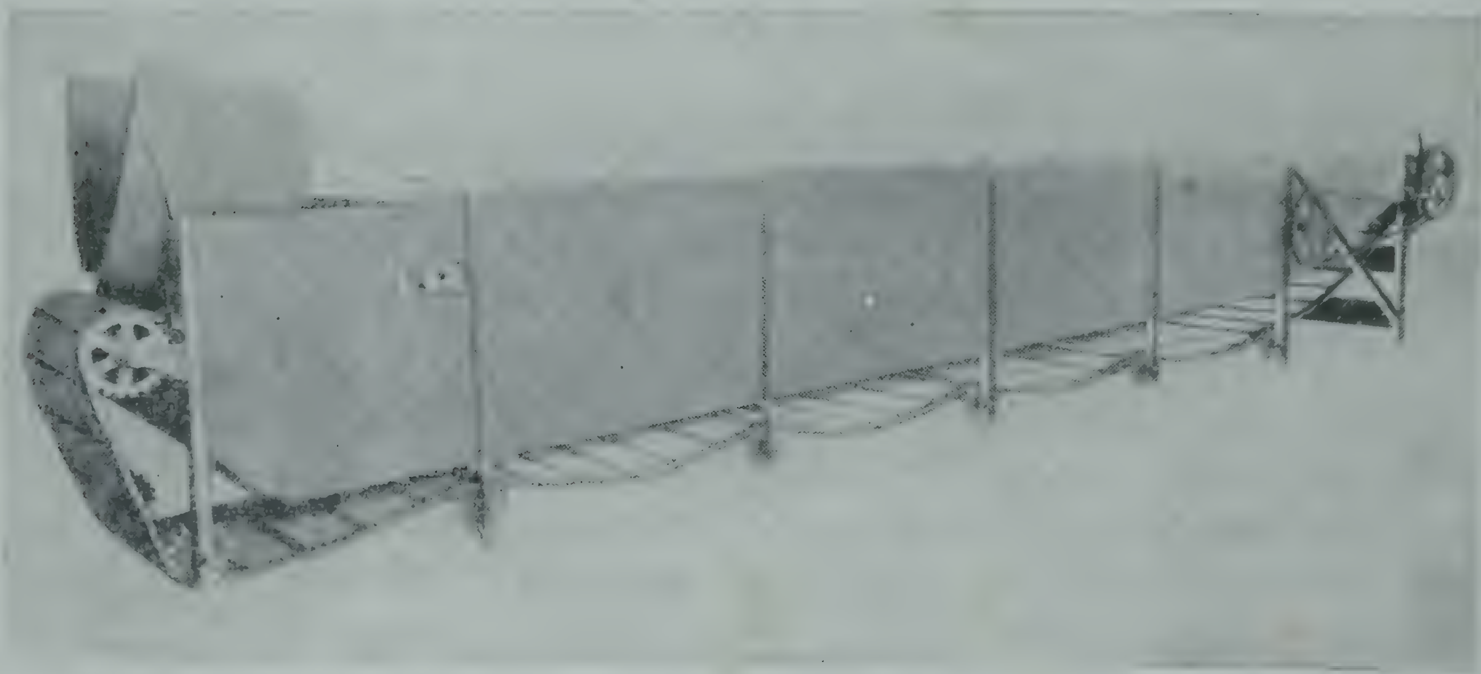


FIG. 15. Spinach blancher draper type. (*Food Machinery Corp.*)

All operators watch the appearance of the peeled fruit closely. If they see that peeling is incomplete, the lye concentration is increased, and if it is penetrating too deeply, it may be diluted. Careful control of the lye concentration will not only save lye but will also prevent excessive loss in weight and undue decrease in size of the halves during peeling.

Length of Immersion in Lye. In California the length of immersion varies from about ½ to about 1½ min. The time of immersion or the concentration of the lye solution can be varied to suit the condition of the fruit. The output of the peeler could be affected, of course, by varying the time of immersion, but usually the lye concentration rather than the time is adjusted.

Amount of Lye Used. The amount of lye used per ton of fruit varies greatly according to the variety, its maturity, and the style of peeling machine used. Most California canners estimate the lye consumption at 5 to 8 lb. per ton of fresh fruit. This estimate agrees well with data developed by T. Douthit of the University of California Food Technology Department laboratory several years ago.

REFERENCES

(See chapters on canning of fruits and vegetables for additional information on washing, blanching, and peeling.)

Adam, W. B., and Horner, G.: The effect of blanching on the nutritive value of canned vegetables, *Canning Research Sta., Campden, England, Ann. Rept.*, 1941, pp. 21–31.

——— and Stanworth, J.: Physical changes occurring during the blanching of vegetables, *Canning Research Sta., Campden, England, Ann. Rept.*, 1941, pp. 32–41.

Bitting, A. W.: "Appertizing, or the Art of Canning," The Trade Press Room, San Francisco, 1937.

Campbell, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

Catalog of canning machinery, Atlas Pacific Engineering Company, Emeryville, Calif.: 1955.

Catalog of canning machinery, Chisholm-Ryder Co., Niagara Falls, N.Y., 1955.

Catalog of canning machinery, Food Machinery and Chemical Co., San Jose, Calif., 1955.

Cruess, W. V.: Blanching and cooling for frozen pack, *Fruit Products J.* **25**(5), 134, 135, January, 1946.

——— and Mackinnery, G.: The dehydration of vegetables, *Univ. Calif. Agr. Exp. Sta. Bull.* 680, 1943.

Dunlap, R. L.: Lye peeling of potatoes, *Food Inds.*, **16**, 969–971, 1944.

Hohl, Leonora A., Swanburg, J., David, J., and Ramsey, R.: Cooling of blanched vegetables and fruits for freezing, *Food Research*, **12**(6), 484–495, 1947.

Holmquist, J. W., Clifcorn, L. E., Heberlein, D. G., Schmidt, C. F., and Ritchell, E. C.: Steam blanching of peas, *Continental Can Co. Bull.*, Chicago, 1954.

Magoon, C. A., and Culpepper, C. W.: Scalding of vegetables for canning, *U.S. Dept. Agr. Bull.* 1265, 1924.

Mercer, W. A. and Townsend, C. T.: Water re-use in canneries, *Natl. Canners Assoc., Research Lab., Bull.* 31-L, May, 1954.

National Canners Association Research Laboratories: *Blancher Studies, Ann. Rept., Research Labs.*, 1954, pp. 8, 9. See also *Natl. Canners Assoc. Inform. Letter*, Mar. 19, 1955.

Pilcher, R. W., et al.: "The Canned Food Reference Manual," American Can Co., New York, 1949.

Wagner, J. R., Strong, F. M., and Elvehjem, C. A.: Nutritive value of canned foods, *Ind. Eng. Chem.*, **39**(8), 985–993, 1947.

Weast, C. A., and Mackinney, G.: Chlorophyflase, *J. Biol. Chem.*, **133**, 551–558, 1940.

Wolters, C. F., Jr., Elledge, N. G., and Kerwin, R. D.: "Lye Peeling," Diamond Alkali Co., Pittsburgh, 1943.

CHAPTER 4

GRADING FRUITS AND VEGETABLES FOR CANNING AND FREEZING

One of the most important factors in determining the quality of processed fruit and vegetable products is careful grading. Various attributes of the raw materials and of the processed products are used as criteria in grading. Size, color, maturity, freedom from blemishes or other defects, symmetry, texture, freedom from damage by mold or insects, flavor, and odor are examples of properties that are taken into account in grading or judging the raw or the finished product. Canners, freezers, preservers, and other processors have become very conscious of the necessity of supplying to the trade and the consumer products that are not only of good quality but that are uniform in quality within each grade. Some of the well-known, nationally advertised brands are worth millions of dollars to their owners because consumers have learned to associate them with uniformly high quality.

Informative Labeling. A number of years ago the label on the can or carton of finished product often did not carry a designation of the quality of the contents of the package. At present, however, some form of grade designation is usually given. In some cases it will be a U.S.D.A. designation, such as U.S. Grade A, B, or C, or U.S. Grade Fancy, Choice, or Standard, or it may be a grade of the Canners' League of California.

Many canners and freezers now have their packs continuously inspected and graded by the U.S.D.A., Agricultural Marketing Administration, and are entitled to state this fact and the U.S. grade on the label.

Object of Grading. Grading of the raw product before processing results in greater uniformity of finished product and in standardization and improvement in methods of preparation, processing, and preservation. It gives the consumer several grades that range in price according to grade. Standard-quality peas are a good, wholesome, and very nutritious food, but cost less than the Fancy or Choice.

In spite of the fact that the label will usually inform the purchaser of the grade of the product, many housewives buy a nationally advertised brand on the assumption that it is of highest quality. Often this assumption is correct, but not necessarily so.

Effect of Variety. Certain varieties of cling peaches, or of peas, or green beans give canned or frozen products of higher quality than do certain other varieties. The processor must therefore take this fact into account in securing the raw material for processing. Plant breeders are constantly striving to improve existing varieties or to produce new and better ones.

Effect of Maturity. In addition to choosing a variety of high-processing quality, the canner or freezer must also make certain that it is harvested at as near optimum maturity as possible. Fruit is usually best for canning at the *firm-ripe* stage, before it has become soft ripe. The term "canning ripe" has a very definite meaning to fruit growers and canners. Immature peaches are apt to be deficient in color and flavor as well as tough in texture from the canners' standpoint, and those that are "just right" for eating fresh are apt to soften unduly during sterilization in the can. The maturity of peas, corn, and green beans for canning or freezing is of critical importance. In some cases the degree of maturity considered best for canning may not be best for the making of jam or for freezing.

Importance of Processing Promptly after Picking. The quality of the finished product is affected very markedly by the length of time that elapses between picking and canning. On this account the raw product should be transferred from the orchard or field to the cannery or freezer in the shortest time possible.

Effect of Temperature. The effect of temperature during shipment to the cannery is also extremely important. Railroad cars and trucks used for shipment of canning fruit should be well ventilated and as cool as possible. It is desirable to allow the fruit to stand in the orchard in open boxes during part of the night to cool before it is loaded into cars. Fruit stored at the cannery should be placed in cold storage or in a well-ventilated room and, except for pears and apples, should be held for as short a time as possible before canning. Pears are usually picked when hard ripe and are ripened at the cannery.

Relation of Sanitation to Quality. Quality is affected by sanitary conditions in the plant. Moldy boxes will often cause spoiling of fruit or tomatoes in shipment or cause them to acquire a disagreeable flavor and odor. Many of the large canneries wash the shipping boxes thoroughly in hot water or in a hot cleansing medium such as dilute lye or sodium carbonate solution and steam them in order to clean and disinfect them before returning them to the grower. Floors, canning tables, conveyers, siruping equipment, sorting belts, and all machinery in the cannery must be washed frequently, and the premises must be kept free of decomposing cannery refuse.

Grading for Quality. Upon its arrival at the cannery, the fruit should be graded roughly for quality. The overripe boxes of fruit should be separated from those of proper maturity. The women employed in cutting and peeling the fruit sort it for quality, usually after peeling or cutting, and some

fruits are again sorted on broad, slowly moving belts by women who are trained for this work. A third or fourth sorting is given by the women who fill the cans with the prepared fruit. Careful sorting is essential to success in commercial canning. Vegetables must also be sorted according to maturity, freedom from blemishes, etc. Peas are graded, by flotation in brine, according to maturity and are sorted on a belt to remove bits of pod, vine, weed seeds, weed pods, and burs. Corn must be sorted by hand according to maturity before it is cut from the cob. As stated previously, such properties as size, freedom from blemishes, mold, or insect damage, color, and damage in handling or preparation are also usually considered in sorting.

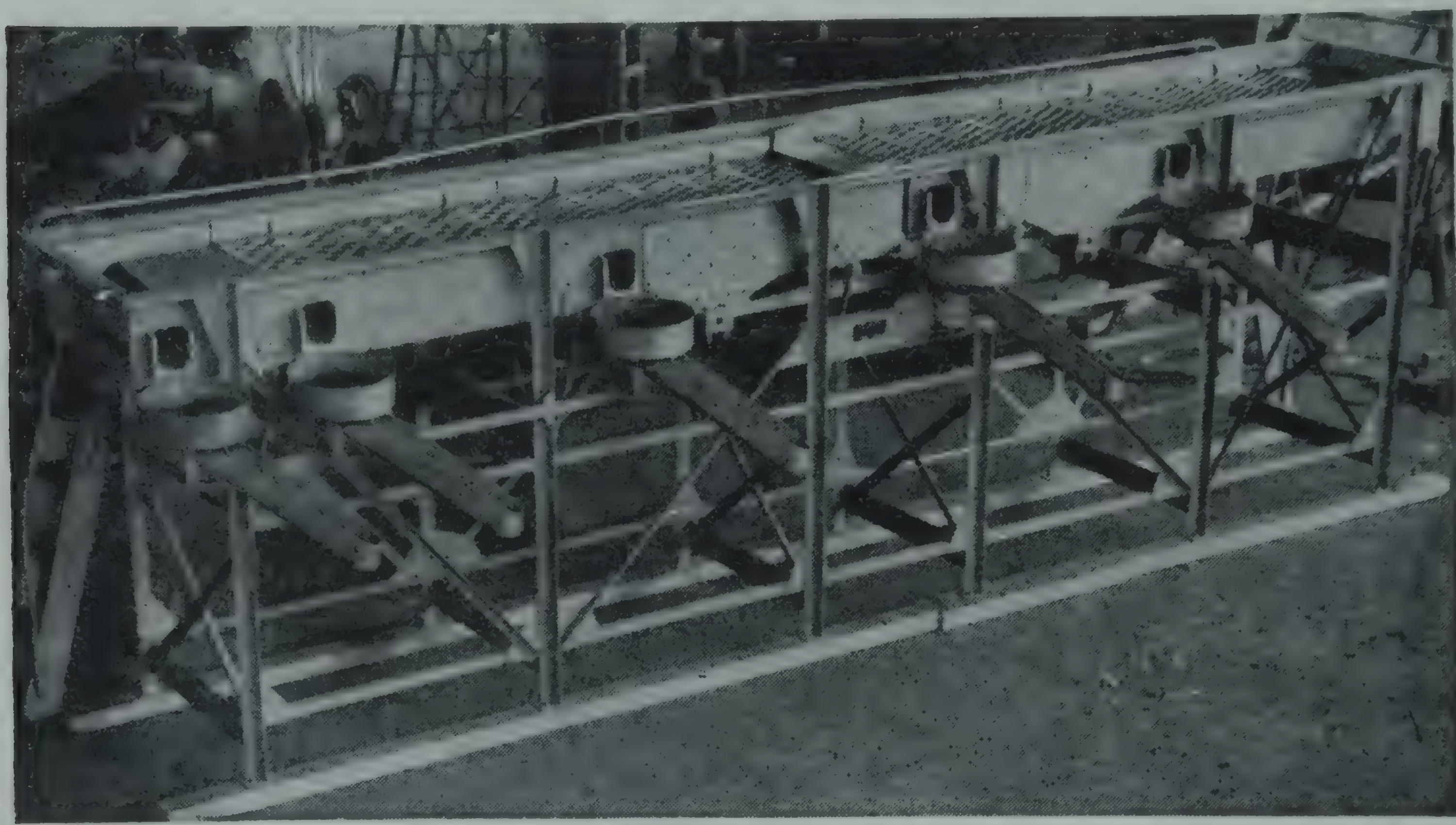


FIG. 16. Size grader for fruits. (*Food Machinery Corp.*)

CANNING-FRUIT GRADES ADOPTED BY THE CANNERS' LEAGUE OF CALIFORNIA

Most of the canners in California grade their fruit according to standards devised and adopted by the Canners' League of California, an organization comprising over 90 per cent of the canners of northern California. These grades are also recognized by canners in California who are not members of the Canners' League. The general specifications for these grades are as follows:

Fancy grade represents fruit of superlative quality, of very high color, ripe yet not overripe, free from blemishes, very uniform in size, and very symmetrical in appearance.

Choice grade represents fruit of fine quality, of high color, ripe yet not overripe, free from blemishes, uniform in size and symmetrical. It is often one size smaller than the Fancy grade.

Standard grade represents fruit of good quality, reasonably good color, reasonably free from blemishes, uniform in size, reasonably uniform in color and degree of ripeness, and reasonably symmetrical.

Second grade represents fruit of second quality, tolerably free from blemishes, tolerably uniform in size, color, and ripeness, and tolerably symmetrical.

Pie, or water, grade represents fruit of pie quality that is wholesome fruit, not suitable to the above grades. It need not be uniform in size, maturity, color, or appearance and may contain a few blemishes. It must not contain decomposed fruit.

Table 3 gives the number of pieces of the different varieties of fruit per No. 2½ can, and Table 4 gives the concentration of sirup used for these different grades. However, the maturity of the fruit, its variety, and the

TABLE 3. NUMBER OF PIECES PER NO. 2½ CAN FOR VARIOUS GRADES OF CANNED FRUITS, AS ADOPTED BY THE CANNERS' LEAGUE OF CALIFORNIA

Fruit	Fancy	Choice	Standard	Second	Pie
Apricots	24 or less, variation 6*	30 or less, variation 7	42 or less, variation 8	No limit	No limit
Cherries:					
Royal Anne	85	105	145	No limit	No limit
Other	100	125	175	No limit	No limit
Grapes, Muscat	No standard	No standard	No standard	No limit	No limit
Peaches	6–12, variation 4	6–15, variation 5	6–21, variation 6	No limit	No limit
Pears	6–12, variation 4	6–12, variation 5	6–21, variation 6	No limit	No limit
Plums	11	....	....	....	No limit

* "Variation" refers to variation in number of pieces in different cans from the same factory. Appearance of the fruit and freedom from blemishes are more important in most cans than the number of pieces per can.

TABLE 4. BALLING DEGREE OF SIRUPS ADDED TO VARIOUS GRADES OF CANNED FRUITS, AS SPECIFIED BY THE CANNERS' LEAGUE OF CALIFORNIA

Fruit	Fancy	Choice	Standard	Second	Pie
Apricots	55	40	25	10	0
Cherries:					
Royal Anne	40	30	20	10	0
Other	40	30	20	10	0
Grapes, Muscat	40	30	20	10	0
Peaches	55	40	25	10	0
Pears	40	30	20	10	0
Plums	55	40	25	10	0

ratio of fruit to sirup will affect the Balling degree of the sirup required.

These may be considered as approximate standards for the five grades of California canned fruits. Many canners use sirups of higher Balling degree than those given in the table and grade their fruit according to size more rigidly than indicated in Table 3.

CHANGES IN CONCENTRATION OF SIRUP AFTER CANNING

After canning, the concentrations of sugar in the sirup and in the fruit tend to equalize. The heavy sirups, therefore, tend to decrease in Balling degree, and the Second grade sirups, if of lower sugar content than the fruit, may increase in Balling degree during storage. There is a fairly definite relation between the concentration of the sirup placed on the fruit at the time of canning and the concentration of the sirup in the fruit and can after canning and storage.

Typical Changes in Concentration of Sirup on Peaches and Pears. According to Bitting, the following relations exist between the ordinary concentrations of sugar and the final concentration after canning and storage of peaches and pears. The concentration in a can after storage and on examination is known as the "cutout" concentration.

The changes in composition of the sirup are due to interchange of soluble solids between fruit and sirup. In most fruits this change occurs without shriveling or without bursting of the fruit, although fruits with tough skins, such as grapes, may burst in a very dilute sirup and shrivel in a very heavy sirup.

TABLE 5. RELATION BETWEEN CUTOUT TEST AND ORDINARY CONCENTRATIONS OF SIRUP USED IN CANNING PEACHES AND PEARS, DEGREES BALLING

Peaches		Pears	
Original sirup	Cutout	Original sirup	Cutout
55	26.1	40	24.1
40	22.2	30	17.9
30	18.5	20	16.6
20	16.1	10	12.9
10	12.3	0	9.3
0	9.0		

SOURCE: A. W. Bitting, *U.S. Dept. Agr. Bull.* 196, p. 45.

Relation between Sirup Concentration at Canning and after Storage for California Fruits. The figures given in Table 6 were obtained from commercial canners and a compilation of published data and must be considered as approximate only, because the composition of the fruit varies

Table 6. Approximate Minimum Cutout Concentration of Sirup from Various Grades of Canned Fruit, Degrees Balling

Fruit	Fancy		Choice		Standard		Second		Pie	
	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage
Apricots, Royal	55	27	40	21	25	17	10	12	0	9
Cherries:										
Black Tartarian	40	23	30	20	20	15	10	12	0	10
Royal Anne	40	23	30	20	20	15	10	12	0	10
Grapes, Muscat	40	28	30	24	20	21	10	17	0	12
Peaches	55	26	40	20	25	15	10	12	0	9
Pears, Bartlett	40	22	30	18	20	15	10	12	0	11
Plums, Green Gage	55	27	40	21	25	17	10	12	0	9

with the season, maturity, locality, and variety and affects the composition of the sirup accordingly (see also Chapters 7 and 8).

Canned Fruits for Salad and Fruit Cocktail. Specifications for the different grades of these two products are given in Chapter 8.

SIZE GRADING OF FRUITS

Cherries, plums, grapes, berries, and olives are graded for size whole, while peaches and apricots are graded after cutting in half or after halving and peeling. Pears are graded for size mechanically before peeling or halving.

Types of Graders. Most fruits are graded over vibrating screens with circular openings of various sizes. In most cases $\frac{1}{32}$ in. is used as the unit of measurement for these holes. The screens are usually five or six in number and are interchangeable so that one machine can be adjusted for different varieties of fruits by simply inserting the size of screen adapted to the fruit. The screens are usually made of copper, as it has been found that this metal will withstand severe use and does not injure the color of the fruit.

Screen Grader. In some graders the large sizes of fruit are removed first. This is accomplished by allowing the smaller sizes to fall through the first screen and permitting the largest size to pass over the end of this screen, where the fruit is conveyed to the canning tables by a belt operating at right angles to the direction of flow of the fruit. In a similar fashion the smaller grades of fruit are separated successively.

In the second style of grader the small sizes are removed first and the largest size is allowed to drop progressively from one screen to the next and

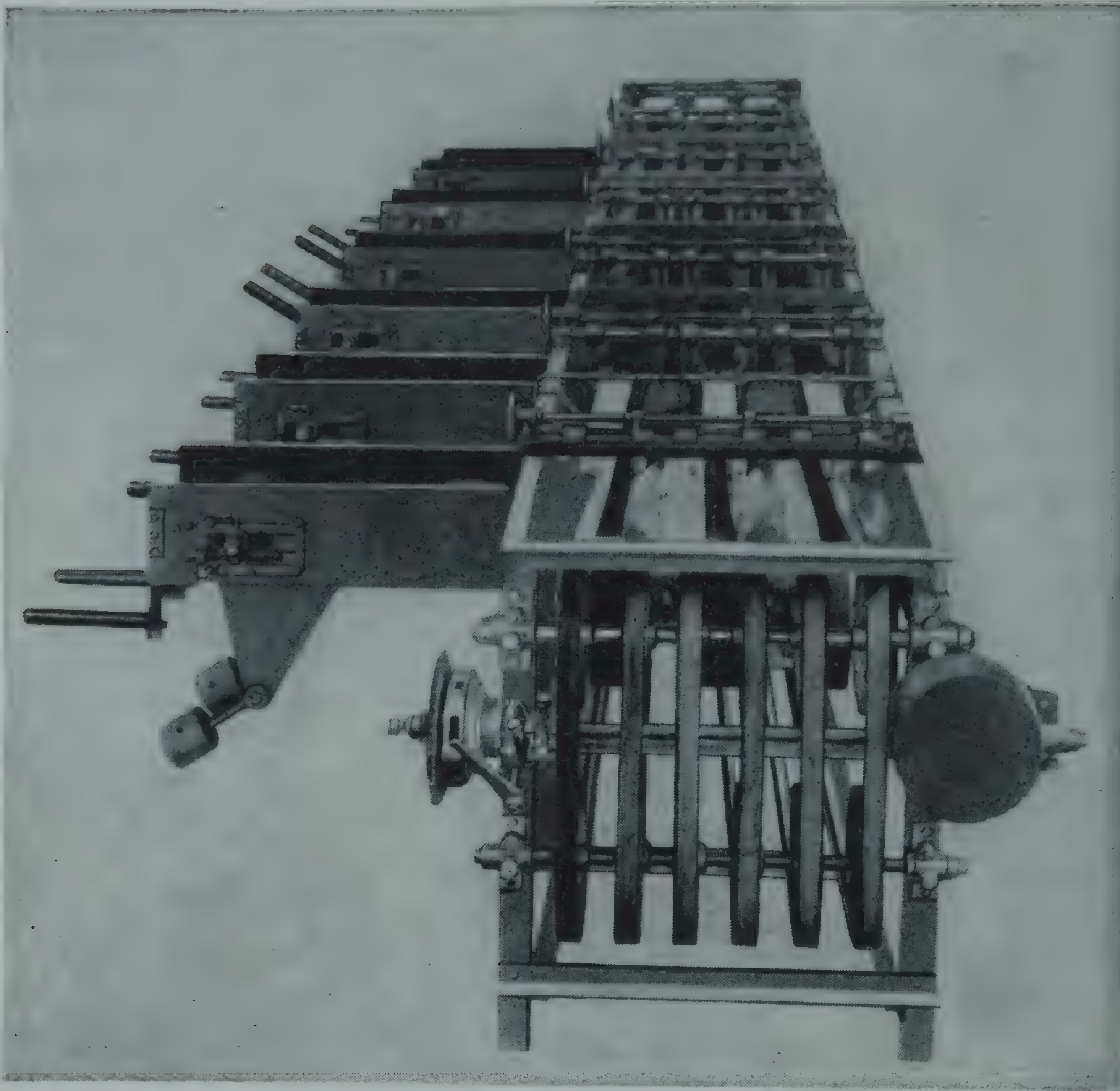


FIG. 17. Diverging belt grader for pears and other fruit. (*Food Machinery Corp.*)

finally to pass over the last screen. This is considered objectionable because the large fruit is subjected to unnecessary agitation, which may result in softening or bruising. This is particularly true of delicate-textured fruits, such as halved apricots.

Another form of screen grader is that used for peas. It consists of a long, revolving perforated cylinder. The perforations are circular and are of increasing size from the entrance to the exit ends.

Roller Grader. The roller grader consists of two rollers, usually about 2 in. in diameter, which revolve from each other and which are closer together at the upper end than at the lower end. As the fruit passes along these rollers, the small fruit is the first to drop through and is removed. The largest sizes are removed last. This style of grader is suitable for spherical, unpeeled, uncut fruit. It has been used more or less successfully for the grading of whole peaches, apricots, oranges, and olives.

"Rope," or Cable, Grader. Olives for canning are usually graded for size

by traveling, diverging, steel endless cables. The distance between the cables is adjustable. For pears, rubber cables are used.

Grading by Weight. A well-known grader for apples and oranges grades the fruit by weight. The individual fruits fall into traveling canvas pockets placed at one end of short counterpoised rods. The rods rest on a long iron strip that serves as a fulcrum. As the fruit is carried along the grader, the distance of the fruit from the fulcrum becomes greater. The cups tilt as the leverage of the fruit becomes greater than that of the counterpoise. The heaviest fruit is removed first, and the lightest fruit last. This grader has proved popular for apples and may have possibilities for grading other fruits for canning.

Pears are graded whole by a roller grader or rubber cable grader and are also graded by hand after peeling, halving, and coring (Figure 17).

Diameters of Openings in Grader Screens for Common Fruits. The usual diameters of the higher grades of canned fruits are shown in Table 7.

TABLE 7. AVERAGE DIAMETER OF VARIOUS GRADES OF CANNED FRUITS (EXCEPT OLIVES)

Fruit	Fancy	Choice	Standard
Apricots	$\frac{56}{32}$ in.	$\frac{54}{32}$ in.	$\frac{50}{32}$ in.
Cherries:			
Royal Anne	$\frac{29}{32}$ in.	$\frac{28}{32}$ in.	$\frac{28}{32}$ in.
Black	$\frac{26}{32}$ in.	$\frac{25}{32}$ in.	$\frac{22}{32}$ in.
Grapes, Muscat	$\frac{26}{32}$ in.	$\frac{25}{32}$ in.	$\frac{24}{32}$ in.
Peaches	$\frac{76}{32}$ in.	$\frac{64}{32}$ in.	$\frac{56}{32}$ in.
Plums, Green Gage	$\frac{56}{32}$ in.	$\frac{50}{32}$ in.	$\frac{42}{32}$ in.
Pears, Bartlett*	8–10 pieces	10–12 pieces	15–17 pieces

* Pieces per No. 2½ can.

SOURCE: After Cruess and Christie, "Laboratory Manual of Fruit and Vegetable Products."

There are no size standards for Second and Pie grades.

Normally the sizes of the various grades of fruit are equal to, or greater than, the diameters given in the table. Considerable range is permitted.

Because ripe olives vary greatly in form, it is customary to grade this fruit according to the number of olives per pound, as indicated in the table on page 64.

Size Grading of Vegetables. Peas, string beans, beets, cucumbers, and asparagus are graded for size, in some cases by screens, cable, or other graders and in others by hand. The method of grading and grade designation vary with the vegetable concerned. Therefore, in order to avoid undue repetition, vegetable grading and tables of size grades will be given in the discussion of canning and pickling of the individual vegetables.

TABLE 8. SIZE GRADES FOR CALIFORNIA RIPE OLIVES

Grade designation	Approximate diameter, in.	Number of olives per pound
Small or Standard	9/16	128–140
Medium	10/16	105–120
Large	11/16	90–105
Extra Large	12/16	76–88
Mammoth	13/16	65–75
Giant	14/16	53–60
Jumbo	15/16	45–50
Colossal	16/16 or above	36–40
Super Colossal	Above 16/16	33 or less

SOURCE: California Olive Association.

GOVERNMENT STANDARDS FOR NET DRAINED CONTENTS

The Food and Drug Administration of the U.S.D.A. has established standards for net contents of cans of certain fruits and vegetables. The investigations upon which these standards are based have been made by the various food and drug inspection laboratories of the U.S.D.A.

The standards as at present established are to be considered as minimum requirements, and in most cases products canned by the usual commercial methods will readily meet or exceed these minimum standards.

The determination of the net drained weight of canned fruits and vegetables is made according to the following directions of the Federal agency.

Draining. For determination of drained weight the contents of No. 2½ cans and cans of smaller size should be emptied on a circular ⅛-inch mesh screen 8 inches in diameter, set in a frame with a vertical side higher than the level of the product on the screen. The contents of the can should be distributed over the screen so as to form a layer of uniform depth, this being accomplished so far as possible by the manner of emptying from the can. Such further handling as is required to level the material on the screen, in order to secure a layer of practically uniform depth, should be done in such a way as to exert no pressure, whereby additional amounts of liquor will be expressed from the material. The period of draining should be 2 minutes in all cases. The manner of determining the drained weight for No. 10 cans is the same as the foregoing, with the exception that a circular ⅛-inch mesh screen 12 inches in diameter is used. This screen should also be set in a frame with a vertical side higher than the level of the product on the screen.

Cans of sizes not mentioned should yield a drained weight of contents which bears

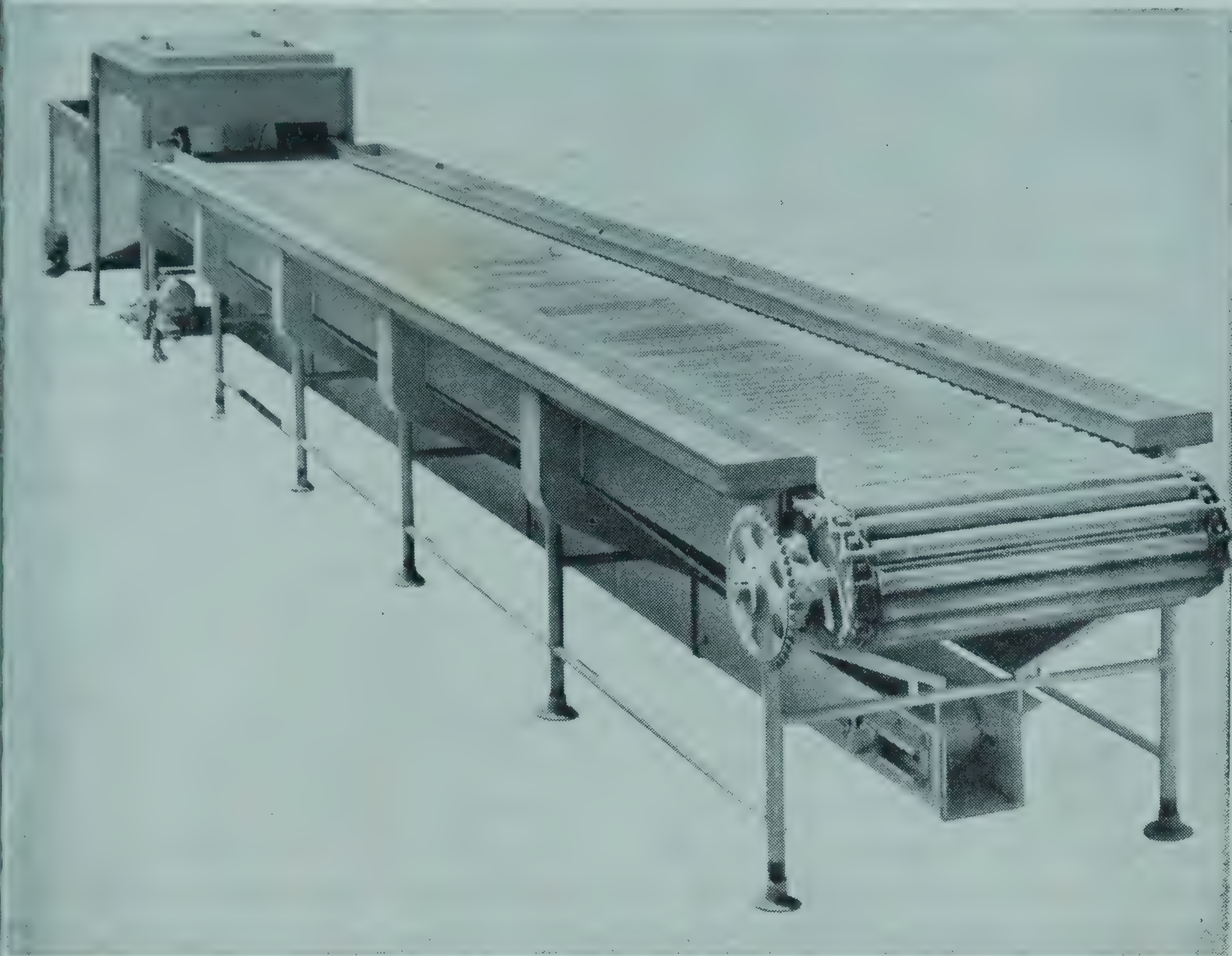


FIG. 18. Roller sorting belt for tomatoes and whole fruits. (*Atlas Pacific Engineering Co., Oakland, Calif.*)

the same relation to the drained weight indicated for the can nearest in size as that existing between the capacities of the cans in question.

In making declarations under the net weight requirement of the Federal Food and Drugs Act, the total weight of the contents of the can, liquid included, should be declared; this Bureau will regard as in violation of the Act interstate shipments of canned foods packed with lighter weights than those indicated. May 5, 1920.

Standards or requirements of the food and drug regulations as at present published can be obtained on application to the Food and Drug Administration, U.S.D.A., Washington, D.C. A Federal agency known as the Agricultural Marketing Administration of the U.S.D.A. now has jurisdiction over the inspection of canned and other processed foods, in so far as grade and quality are concerned.

McNARY-MAPES ACT

The McNary-Mapes Act was passed by the United States Congress on July 8, 1930. Its purpose was to protect the consumer by compelling the canner to label certain canned products of quality below Standard as

Substandard. For fruits the Federal government's Standard quality corresponds closely with the California Canners' League Standard grade. The provisions of the Act are enforced by the Food and Drug Administration.

Canned fruits of Substandard quality may be labeled "Below U.S. Standard. Low quality. Good food. Not high grade." Canned vegetables provided for in the act may be labeled "Below U.S. Standard. Low quality but not illegal." The substandard foods must be edible, sound, and not decomposed. The Act is a criminal statute. Violators can be prosecuted in court. Conviction carries a fine and possible dumping of the product.

Canned peaches may be taken as an example to illustrate provisions of the Act. Peaches are not classified according to variety, no distinction being made between freestone and clingstone peaches. The sirup of Standard grade must be at least 14° Brix. The fruit must be normal in color and free of abnormal odors and flavors. The pieces must not be excessively trimmed. Not more than 20 per cent of the pieces in the can may show blemishes of any sort whatsoever, and no single piece may show a blemish greater in area than 5 per cent of the surface of the affected piece. No piece may be less than $3/5$ oz. in weight. The largest piece shall not be more than 80 per cent greater in weight than the smallest piece in the can. Texture must be satisfactory; it must not be so soft that the fruit loses its shape when poured into a dish or so hard that it will not be penetrated by a $5/32$-in. needle under a pressure of 300 grams. The halves must be unbroken, except that one broken half next to the lid is allowed, the assumption being that it is broken in opening the can. Not more than 1 sq. in. of peel per pound of fruit is allowed. The drained weight must equal or exceed 60 per cent of the net maximum content of the can, except that a tolerance of one piece per can is allowed to avoid overfilling.

Similar requirements have been made for cherries, pears, and apricots. The sirup for pears must be 13° Brix or greater. For details see references given at the end of this chapter.

Canned peas will serve as an example of the McNary-Mapes grades for vegetables.

To be of Standard quality the peas must be tender, immature, unbroken, normally flavored, and normally colored and may be canned with or without water. There must not be more than 4 per cent by count of off-colored peas. At least 80 per cent of the peas must have the two cotyledons intact and held together by the skin. There must not be more than one piece of foreign material of the same specific gravity as the peas per 2 oz. (thistle heads, daisy buds, etc.). Peas are considered immature if 90 per cent or more by count are sufficiently soft so that either cotyledon is crushed by a weight of less than 2 lb. (907.2 grams); or if not more than 20 per cent of the peas sink in a brine of 1.12 specific gravity at 68°F.; or if the alcohol-insoluble matter does not exceed 23 per cent; or if less

than 25 per cent of the peas by count are swelled to such an extent as to rupture the skin sufficiently to separate the broken edges $\frac{1}{16}$ in. or more.

UNITED STATES QUALITY GRADES FOR CANNED VEGETABLES

By virtue of authority granted by act of Congress in 1933 the U.S.D.A. promulgated grades for most canned vegetables. From time to time the specifications are revised. They are used by the Agricultural Marketing Administration in its continuous inspection. The requirements for the various United States grades for canned peas and tomatoes are given briefly as illustrations.

In the U.S.D.A. standards for grades of canned peas effective May 13, 1955, United States Grades A, B, C, and D are defined approximately as follows:

U.S. Grade A, or U.S. Fancy, is the quality of canned peas that possess similar varietal characteristics; that have a good flavor and a good liquor; that are practically free from defects; that are tender; and that score not less than 90 points in accordance with the Department's scoring system.

U.S. Grade B, or U.S. Extra Standard, canned peas possess similar varietal characteristics; have a good flavor and reasonably good liquor; are reasonably free from defects; are reasonably tender; and score not less than 80 points when judged as above.

U.S. Grade C requirements are worded in a manner similar to those for U.S. Grade B, except that the word "fairly" is used to qualify the various attributes and the peas must score not less than 70 points.

Substandard grade (sometimes designated Grade D) canned peas are those that do not meet one or more of the requirements for Grade C.

Maturity is gauged by flotation of a sample of the canned peas in brine of 11 and 13° salometer. For example, not more than 12 per cent of the peas may sink in 10 sec. in brine of 11° salometer, and not more than 2 per cent in brine of 13° salometer for Grade A. The scoring system given in the 1955 standards is as follows:

	Points
Liquor	10
Color	10
Defects	30
Maturity and tenderness	50
Total	100

Detailed directions are given in published standards for arriving at numerical values for each of the four attributes listed in the scoring system.

U.S. Grade A, or U.S. Fancy, canned tomatoes are defined about as follows in a recent revision of the standards for this product. The drained

weight must be not less than 66 per cent of the capacity of the container, except as allowed for whole tomatoes of this grade; they must possess a practically uniform, good red color; be practically free from defects; possess a normal tomato flavor and odor; and must score not less than 90 points in accordance with the Department's scoring system.

For U.S. Grade B, or Extra Standard, canned tomatoes the drained weight must be at least 58 per cent of the capacity of the container; not less than 70 per cent of the drained solids must be whole, almost whole, large pieces or combination of such pieces; they must be of reasonably good, typical color, practically free from defects, and of normal tomato flavor and odor; and they must score not less than 75 points.

For U.S. Grade C, or U.S. Standard, the drained weight must be not less than 50 per cent of the capacity of the container and the drained solids may be less than 70 per cent of the net contents. The qualifying word "fairly" is used to describe flavor, color, etc., and the product must score not less than 50 points.

U.S. Grade D, or Substandard, is that which does not meet one or more of the requirements for Grade C.

The scoring system for grading commercially canned tomatoes is as follows:

	Points
Drained weight	20
Wholeness	20
Color	30
Absence of defects	30
Total	100

See the published standards of the Department for detailed directions for arriving at numerical values for each of the attributes given in the scoring system.

United States Grades have been established and published for other canned vegetables and may be had on application to the U.S.D.A., Production and Marketing Administration, Washington 25, D.C.

UNITED STATES QUALITY GRADES FOR CANNED FRUITS

Grades A, B, C, and D have been promulgated for most canned fruits. The wording is similar for the different fruits; consequently only cling peaches will be considered.

U.S. Grade A (Fancy) canned peaches are units of peaches of similar varietal characteristics; are practically uniform in color and practically free from defects; possess a firm but tender fleshy texture and a normal peach flavor; and score not less than 90 points.

In describing U.S. Grade B (Choice) canned peaches, the word "reasonably" replaces "practically," and they must score not less than 75 points.

In describing U.S. Grade C (Standard), the word "fairly" replaces "reasonably," and the peaches must score at least 60 points. The sirup must test not less than 14° Balling.

U.S. Grade D is wholesome fruit that does not meet one or more requirements for Grade C.

Sirup-density cutouts are not set in the standards; nevertheless Fancy fruit is usually packed in sirup of 55° Balling, Choice in 40° Balling, Standard in 25° Balling, and Seconds in 10° Balling. However, if the canner uses the words "extra-heavy sirup" on the label, then the cutout must be 24° Balling or above; "heavy sirup," 19 to 24° Balling; and "light sirup," 14 to 19.9° Balling; all at 68°F.

The scoring scheme for canned peaches is as follows:

	Points
Color	20
Uniformity of size and symmetry	15
Absence of defects	30
Character of fruit	35
Total	100

Details are given for arriving at the ratings for each of the four characteristics and can be had on application to the U.S.D.A., Agricultural Marketing Administration.

Continuous Inspection. Canners, freezers, and other food packers who so desire may now arrange to have their products inspected and certified as to grade and quality by inspectors of the Agricultural Marketing Administration of the U.S.D.A. The packer may state on his label that the product has been inspected and approved by this service. Some canneries and most freezers of fruits and vegetables in Oregon, California, and Washington make use of this service. Throughout the working day one or more inspectors of this Federal agency are on duty.

A small charge per case or other unit is made by the service to cover the salaries of the inspectors and other operating expenses. It is not tax-supported.

Fill of Container. The same Act under which grades for canned foods were, or are being, established also provides for fill of container. If the level of the contents of the can is more than 10 per cent below the top, measured to the underside of the lid, the can is considered "slack-filled;" this is the general requirement. However, the maximum allowable head space for each product in each size of container commonly used for the product is also specified. For example, the maximum head space for peas in No. 1 Tall cans is $^{9}\cdot\frac{9}{16}$ in.; for a No. 2 can, $^{9}\cdot\frac{7}{16}$; and for a No. 10 can $^{13}.\frac{6}{16}$ in.

For fruits the requirements are similar except that, even if the product meets the maximum head-space requirement, it may be termed slack-filled if it is evident that more fruit could have been put in the can without damage. For fruits also the weight of the fruit must not be less than 60 per cent of the weight of water to fill the can completely at 68°F. Thus if the can will hold 29.8 oz. of water, the can must have on cutout not less than 0.6 by 29.8, or 17.88 oz. of drained fruit.

If the canned product (fruit or vegetable) does not meet the minimum fill requirements, it must be labeled "Below U.S. Standard. Slack fill."

IN-PLANT QUALITY CONTROL

Present-day canneries, freezers, and preserving plants maintain quality-control laboratories and staffs. Throughout the production season the fresh fruits and vegetables, as well as those in process, and the finished products are carefully inspected under a continuous system. The data are recorded on carefully designed, comprehensive data sheets. This quality control is in addition to that conducted by the U.S.D.A., Agricultural Marketing Administration, Processed Products Inspection Division, provided the packer is making use of the Federal service.

General Principles. While the laboratory and other tests used in quality control vary considerably with the kind of food product and other conditions, there are several more or less basic principles, or requirements, that are common to quality-control programs for all fruit and vegetable products. For example (1) both the raw material and the finished product must be considered; (2) raw-material control begins in the field or orchard, making it essential to supervise or keep in close touch with cultural practices, ripening, and harvesting of the crop; (3) inspection and testing of frequent samples on the production line are necessary during preparation and processing; (4) throughout the day samples should be examined in the laboratory; (5) at least some of the tests should be quantitative and objective, i.e., not influenced by personal opinion, but measurable by instrument or by chemical means (such as titration of acidity, measurement of pH value, or mold count by microscope); (6) the observations should be made by personnel who are well trained for the job and who have no other duties; and (7) sampling and testing on the production line must be frequent so that if some unforeseen change in raw-material quality or operating conditions should arise suddenly, the inspector will note the change before a large amount of off-grade product is packed. Therefore, sampling at definite, rather frequent, intervals is desirable. In an olive-pickling plant this may be twice a day, but in a jam factory it may be at 10-min. intervals, and in a fruit cannery it may be even more frequent.

In addition to inspection of the fresh fruit and vegetables, of those in

process and of the finished product, it should also include the empty containers such as cans, can lids, glass jars and caps, and cartons, as well as such items as salt, sugar, corn sirup, pectin, citric acid, and others. Quality, appearance, or flavor may be greatly injured by faulty containers or ingredients.

There should be a laboratory or sampling room set aside and equipped for this purpose.

Each day's pack should be sampled, and on the following morning the samples should be opened and examined by representatives of the various departments, such as field department, production office, and sales and quality-control departments. Any serious faults in raw material or processing that have escaped the attention of quality control can then be detected and corrective measures taken before it is too late.

It is good policy for the chief of quality control or the superintendent to let the workers in the more important operations know occasionally whether quality and grade requirements are being met satisfactorily. Such action improves morale and quality of workmanship.

Roving Inspection. The chief of the quality-control department or other responsible, experienced member of the production staff can often be of great service in maintenance of quality by making occasional trips through the plant during the day. His experienced eye will catch such conditions as careless sorting, a blancher not operating properly, or a filling machine causing excessive damage to product or not filling cans or jars uniformly. The mere fact that he makes such inspection tours tends to make the workmen more careful and observing, with resultant benefit to quality of finished product.

Discussion of Samplings. As previously mentioned, it is highly desirable to cut, or open, each morning samples of the previous day's pack, with representatives present from all departments. A full and frank discussion of these daily "cuttings" is productive of beneficial results qualitywise, as they represent the views and observations of a considerable number of experienced food technologists rather than of the quality-control man only.

A Typical Example. The procedure followed in a large California cannery during the canning of freestone peaches in order to produce a canned product of exceptionally high quality and a high yield of the top grades of Fancy and Choice will serve as an illustration.

The field-department representative makes frequent visits to the orchards as the fruit is ripening and decides when the fruit in a given orchard is to be picked. He closely supervises picking by consulting with and advising the grower or orchard foreman before picking begins and during picking. An attempt is made to deliver to the plant only fruit that is of the desired range of size, of optimum ripeness, as nearly free of blemishes

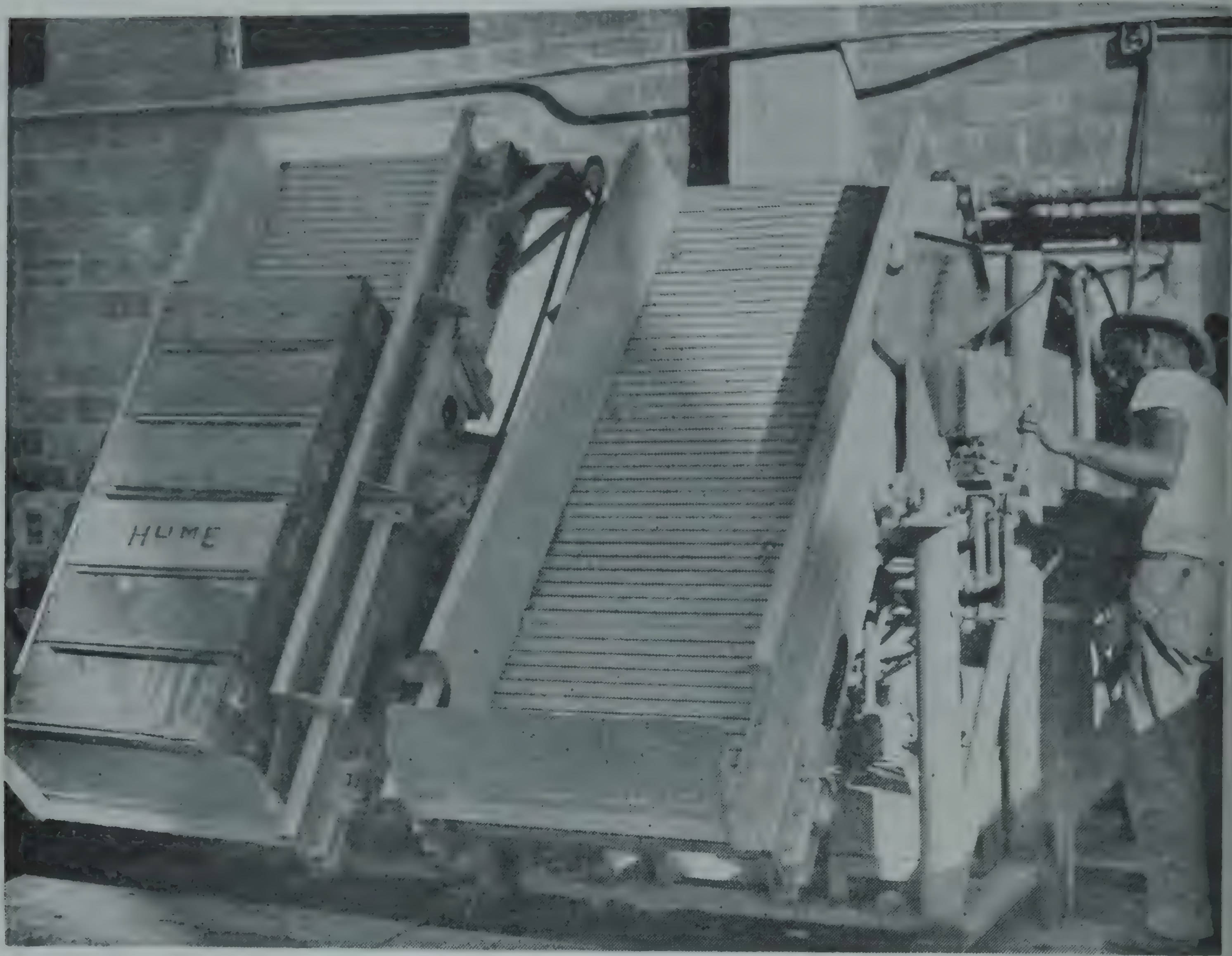


FIG. 19. Humbert lug-box dumper. (*Atlas Pacific Co., Oakland, Calif.*)

as possible, and with a minimum of bruising. Also he sees to it that the fruit, after picking, is not allowed to stand in the orchard very long, as it rapidly deteriorates in quality during standing in lug boxes or baskets on a hot day.

At the plant the peaches are canned promptly after arrival. They first are sorted from a slowly moving, wide belt. They are pitted and halved by hand, as a very large proportion of the freestone peaches in California have split pits, and hence do not lend themselves well to mechanical pitting. Some sorting is done by the pitters. The halved peaches are then steamed to loosen the skins; they are chilled by sprays of cold water; and the loosened peels are removed by hand.

The peeled fruit is inspected and rigorously sorted from a broad belt, only the practically perfect halves being allowed to travel to the Fancy and Choice filling stations. The Standard, Second, and Pie grades are placed on their respective conveyers.

At the filling station the halves are packed by hand in rotary, so-called "hand-pack" fillers. The girls who operate the fillers remove any pieces of fruit that are below grade. Sirup is added by machine, cans and contents are prevacuumized, and the cans are sealed under vacuum or in a steam-flow double seamer.

The "heart" of quality control in this plant is continuous on-line inspection; i.e., an experienced girl takes a can of the peaches frequently from the conveyer on its way to the siruping machine, empties the contents into a pan, and inspects each piece of fruit critically. Usually the fruit is of the quality that it is supposed to be, such as Choice; but if she finds that it is coming through as Standard or as Fancy instead of Choice, she immediately notifies the foreman, or other responsible person, who can take steps to correct the condition that is responsible for the off grade. If it is below Choice in this case, but is packed as Choice, the canner's reputation with distributor and consumer will suffer; if it is Fancy instead of Choice grade, he will not get as large a return as he should, as the Fancy grade commands (or should command) a higher price.

In this plant many samples of the canned product are taken of each day's pack. Some are cut and examined at once; others are held for the next morning's sampling. The cannery has U.S.D.A. Processed Products continuous inspection. The Federal inspectors and the cannery's quality-control men cooperate closely; thus every lot is double-checked. The Federal specifications and quality-grade designations of A, B, C, and D are followed.

In the laboratory the following information is recorded: line number in plant from which sample was taken, vacuum in can, fill-in weight, cutout weight (weight after opening of can), total net contents, number of pieces per can, weights of broken pieces and frayed pieces, flavor, color, texture, odor, supposed grade, actual grade, condition of sirup, condition of can, and any miscellaneous data. Uniformity of quality is also observed, i.e., whether or not the quality of contents of different samples is equal.

The laboratory examination of other varieties of fruit will differ somewhat from that given for freestone peaches and will vary, of course, in different canneries.

In the chapters on canning of fruits and vegetables, freezing of these products, canning of olives, production of jellies and jams, and packing of dried fruits, additional information on quality control will be given.

REFERENCES

Campbell, C. H.: "Campbell's Book: Canning, Pickling, Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

Campbell, H. C.: Notes on the tenderometer, *Western Canner and Packer*, **31**(6), 113, 114, 1939.

Canners' League of California: Specifications for California canned fruits, San Francisco, 1955. A circular.

Cleland, T. M.: "The Munsell Color System," Universal Color Standards, Baltimore, 1931.

"A Complete Course in Canning," The Canning Trade, Inc., Baltimore, 1946.

Dawson, E. H., and Harris, B. L.: Sensory methods for measuring differences in food quality, *U.S. Dept. Agr., Agr. Inform. Bull.* 34, 1951.

Gaylord, F. C., and Cleaver, H. M.: Grading tomatoes for quality, *Purdue Univ. Agr. Expt. Sta. Bull.* 317, 1927.

Hirst, F., and Adam, N. B.: The factory inspection of canned fruits, *Univ. Bristol, Canning Research Sta., Canners' Bull.* 4, 1932.

Howard, A. J.: "Canning Technology," J. and A. Churchill, Ltd., London, 1949.

Hunziker, O. F.: Quality control suggestions for the small cannery, *Canning Trade*, **74**(44), 7, 8; **74**(45), 9, 10, 20, 1952.

Lamb F. C.: Chap. 28 in D. K. Tressler and M. A. Joslyn (eds.), "Fruits and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

Lee, F. A.: Determining the maturity of peas, *Ind. Eng. Chem.*, **13**, 38–40, 1941.

Maerz, A., and Paul, M. R.: "A Dictionary of Color," McGraw-Hill Book Company, Inc., New York, 1950.

Morris, T. N.: "Principles of Fruit Preservation," Chapman & Hall, Ltd., London, 1946.

Q.M. Food and Container Institute, Quartermaster Corps: "Food Acceptance Testing Methodology," Chicago, 1954. A symposium.

Seaton, H. L., and Huffington, J. M.: Raw product quality control, *Continental Can Co., Research Dept., Bull.* 26, 1951.

Tressler, D. K., and Evers, C. F.: "The Freezing Preservation of Foods," chap. 25, Avi Publishing Co., New York, 1947 (revised 1956).

U.S. Department of Agriculture, Agricultural Marketing Administration, Processed Products Division: U.S. Standards for processed fruit and vegetable products. Each product's specifications printed separately. Specify variety and product in applying for specifications. Free on application to the Department.

CHAPTER 5

SIRUPS AND BRINES USED IN CANNING

In canning, sirups are added to fruits and brines are added to vegetables to improve the flavor, fill the spaces between the pieces of canned product, and aid in the transfer of heat during processing.

Sugars Used in Canning. The principal sugar used in canning is sucrose, i.e., cane or beet sugar. Dextrose (corn sugar) is also important in fruit canning. Cane and beet sugars are identical in chemical composition and are used interchangeably in commercial canning.

At one time an impure grade of cane sugar known as "Central American," or "centrifugal sugar," was used to a limited extent in the canning of fruits of dark color where the amber color of the sirup would not be an objection. Another grade of sugar of higher quality than the centrifugal sugar is that known as "plantation-clarified."

Although such sugars are no longer used in California canneries it is possible that they might prove appropriate for use in certain tropical countries or in countries in which the grade requirements for commercially canned fruits are less exacting than in the United States.

Unrefined sugars may occasionally contain sulfur dioxide, which may form hydrogen sulfide in the cans and a black deposit of metallic sulfide. It also hastens the corrosion of cans.

Invert Sugar. The principal sugar in all these commercial sugars is sucrose, $C_{12}H_{22}O_{11}$, which on hydrolysis yields equal amounts of glucose and fructose. The hydrolyzed product is known as "invert sugar." It is considerably sweeter than sucrose.

For some purposes sucrose sugar is dissolved in water, inverted with citric acid or with invertase, and concentrated to a heavy sirup, used extensively in candymaking.

Glucose. Corn sugar, or glucose, in the form of a heavy sirup containing dextrins, is sometimes used in the manufacture of low-priced jams and jellies. It is very much less sweet than cane sugar, is produced from cornstarch by hydrolysis under pressure with dilute hydrochloric or sulfuric acid, and possesses the chemical formula $C_6H_{12}O_6$. The crystalline product (dextrose, glucose) is now obtainable in very high purity and may be used in canning or preserving without declaration on the label. It is now used

very generally in combination with cane sugar in canning fruits. Corn sirups are now produced for use with sucrose sirups in the canning of fruits (see next section on liquid sugar). Up to 25 per cent of the sugar in the sirup used in the canning of fruit may be dextrose.

A corn sirup in which most of the sugar is maltose is made by hydrolysis of the starch with diastase, an enzyme, and concentration to a heavy sirup.

As used in commercial canning corn sugar is usually obtained as a corn sirup. It is usually delivered in tank car or truck tank.

Liquid Sugar. At present most fruit canners purchase much of their sucrose requirements in the form of a highly refined, heavy, sucrose sirup, usually of 67° Brix. It is also used extensively in carbonated beverages (soda water), candies, frozen desserts, and to a lesser extent in bakery products and with frozen fruits.

Refined Syrups and Sugars, Inc., of New York, is reported to have developed this product in Brooklyn in 1925. Its acceptance by the food industries was slow, being hampered by the depression of the thirties and by the Second World War, as well as by the conservatism of commercial users of sugar.

Following the Second World War its use rapidly expanded, with the result that at present 1 lb. out of every 5 lb. of sucrose used in the United States is in the form of "liquid sugar." This name was given the product early in its history. In 1953 approximately 847,000 tons of sucrose was used in this form.

It can be made by merely dissolving refined cane or beet sugar in high-quality water; or more commonly by centrifugal washing of so-called raw cane sugar, either domestic or imported; dissolving in water; clarifying with lime and phosphoric acid; filtration; decolorizing with activated carbon; filtering; decolorizing a second time; filtering and concentrating in a vacuum pan to 67° Brix. An additional treatment often given is with ion-exchange resins to remove ash constituents, any residual color, and organic acids, yielding a sirup of high purity. If made from beet sugar the refined sugar is dissolved in water to give a sirup of 67° Brix; the beet-sugar manufacturing process requires final crystallization in order to obtain pure sucrose.

The sirup is delivered in tank cars or tank trucks to the cannery or other user where it is stored in large enclosed cylindrical stainless-steel tanks or in plain steel tanks lined with a suitable coating. In order to prevent growth of microorganisms in the head space in the tank, a battery of ultraviolet lamps is installed above the sirup level. Also, the distributors of liquid sugar strongly recommend that a current of air be passed continuously through the head space to prevent moisture condensation. There are usually two storage tanks so that after one is emptied it may be cleaned and sterilized.

The sirup is handled by pump from the car or truck into the storage tank, and another pump and piping system delivers it as needed to the canner's sirup room. The pipelines for handling the sirup must be pitched (inclined) sufficiently to permit complete draining so that they may be washed and sterilized regularly.

In California corn sirup is handled in the same manner as liquid sugar at canneries. It is then used in place of crystalline dextrose sugar, previously mentioned.

Such sirups (cane or corn) have certain advantages over the dry sugar. They are usually slightly less costly per pound of sugar used. Their use results in a very great saving in cost of labor as the sirups are handled by pump, whereas the dry sugars are usually delivered in bags that must be lifted by hand, trucked to the sugar-storage space, stacked, and later trucked to the sirup-making department and emptied by hand.

Secondly, much valuable floor space is released for other use as the storage tanks are placed outside the plant. When dry sugar in sacks is stored, rodents or cats may have access to the storage area and may contaminate some of the sugar; the sirup tank is more sanitary for storage. There is less waste of sugar, as the sirup is in a closed system; bags of sugar often break or are torn, with resultant loss of sugar.

Use of the sirup saves time as the sirup can be delivered to the sirup-making department instantly by starting the pump and opening a valve. It simplifies cannery operation and reduces traffic on the cannery floor.

It can be measured by meter, thus saving much time and labor necessary in using dry sugar. The meter can be set to deliver any desired volume of sirup.

Use of liquid sugar and other sirups makes for more orderly and efficient operation in the plant. It also eliminates pilferage of sugar, which has been troublesome in some plants in the past.

Much of what has been said in favor of liquid sugar is summed up in the phrase "greater convenience at less cost."

Preparation of Sirup for Canning. In most canneries the sirup-preparation room is located on the floor above the fruit-preparation and canning rooms and the sirups are transferred by gravity through pipes to the siruping machines. The sugar formerly was dissolved in a small amount of water to yield a heavy sirup, usually of 60 to 65° Balling or Brix. Glass-lined, i.e., enamel-lined, or stainless-steel tanks have been found most satisfactory for the sirup. The tank in which the heavy sirup was prepared is fitted with a steam-heated copper coil or open steam jets, and the water and sugar are heated together until a clear sirup is obtained. Often a steam-jacketed kettle was used for preparing the sirup. Some impurities coagulated and were removed by skimming, and the heavy sirup was further clarified by passing it through cloth before it was transferred to the

FIG. 20. *Upper:* Stainless-steel sirup tanks in a fruit cannery. *Lower:* Sorting lye-peeled peaches.

diluting vats in which the heavy sirup of 60 to 65° Brix was diluted to give sirups of the Brix degrees used for Fancy, Choice, Standard, and Second grades of fruit. Each tank is connected to a corresponding siruping machine in one of the canning lines on the floor below. The sirup is diluted by mixing measured quantities of heavy sirup with water to give the desired Brix, or Balling, degree. The grades of sirup used for the different fruits have been given in Table 4.

Most canneries now purchase their sugar in the form of a heavy, colorless sirup, as described in an earlier section on liquid sugar. It is pumped to the sirup department and diluted to the desired Brix degree. Often a blend of sucrose and corn sirup is used. The blend must contain sucrose equal to or exceeding 75 per cent of the soluble solids present.

Testing the Sirup. The sirup must be tested accurately before use so that the sirup added to the cans of fruit will be of uniform composition

and the cutout test, Brix degree of the sirup after canning and processing, will not be appreciably above or below the established standard. If an inaccurate instrument is used or the testing is done carelessly, considerable loss may be incurred by use of sirups that are unnecessarily high in sugar content; or, on the other hand, sirup too low in sugar content for the grade may be used, giving a canned product below standard in sugar content for the grade.

If we consider canneries of moderate size using 25,000 to 50,000 lb. of sugar per day and assume that the sirups used average 2 per cent too high in sugar content, this will correspond to a loss of 500 to 1,000 lb. of sugar per day.

The instrument commonly used in canneries for the testing of sirups is the Brix, or Balling, hydrometer, which gives the per cent of sugar in the sirup. It is practically always necessary to make a temperature correction, since the hydrometers are usually calibrated for use at 17.5 or 20°C. (63.5 or 68°F.). Each instrument used by canners usually covers only 10° Brix, e.g., 10 to 20, 20 to 30, 30 to 40, 40 to 50, and 50 to 60° Brix, respectively, and are graduated in $\frac{1}{10}$° divisions. The canner should buy only the best hydrometers, since accuracy is of great importance. It is well to have for reference purposes a set of hydrometers tested and certified by the National Bureau of Standards or other similar agency.

Brix and Baumé. The Brix hydrometer is the same as the Balling. The Baumé hydrometer used in some canneries was originally designed for the determination of salt in brines and was originally calibrated by determining the resting point of the hydrometer in water, which was taken as zero on the scale, and the resting point in a 10 per cent salt solution, which was taken as 10° Baumé. Points above or below 10° were divided into equal scale divisions. See Table 9 for relation between Brix and Baumé degree and the paragraph on brine hydrometers for salometer degree.

Testing Hydrometers. Owing to the fact that continued use of the hydrometer in hot sirups affects its accuracy, it should be checked frequently by more accurate instruments. Hydrometers with long stems, and therefore of greater distance between divisions, are more easily read than hydrometers with short stems. It is desirable for the canner to have duplicate or triplicate sets of accurate hydrometers. Table 9 gives the relation between specific gravity, Balling degree, and Baumé degree.

Before removing samples from the sirup tank the contents of the tank should be thoroughly mixed. Compressed air may be used to advantage in stirring. In reading the hydrometer the bottom of the meniscus (level of the sirup) is read.

Temperature Corrections. As previously stated, hydrometers are calibrated for use at a "standard" temperature such as 15.5, 17.5, or 20°C. (60°, 63.5, or 68°F.). The calibration temperature is printed on the stem of

Table 9. Relation of Balling, Specific Gravity, and Baumé

Balling degree or Brix	Specific gravity	Baumé degree	Balling degree or Brix	Specific gravity	Baumé degree
1	1.0038	0.55	38	1.1692	20.80
2	1.0077	1.10	39	1.1743	21.40
3	1.0117	1.70	40	1.1794	21.90
4	1.0157	2.20	41	1.1846	22.40
5	1.0197	2.80	42	1.1898	23.00
6	1.0237	3.30	43	1.1950	23.50
7	1.0277	3.90	44	1.2003	24.00
8	1.0318	4.40	45	1.2056	24.60
9	1.0359	5.00	46	1.2110	25.00
10	1.0401	5.55	47	1.2163	25.60
11	1.0443	6.10	48	1.2218	26.10
12	1.0485	6.70	49	1.2272	26.70
13	1.0527	7.20	50	1.2327	27.20
14	1.0570	7.80	51	1.2383	27.70
15	1.0613	8.30	52	1.2439	28.20
16	1.0656	8.90	53	1.2495	28.75
17	1.0700	9.40	54	1.2551	29.30
18	1.0744	10.00	55	1.2608	29.80
19	1.0788	10.50	56	1.2665	30.30
20	1.0832	11.10	57	1.2723	30.80
21	1.0877	11.60	58	1.2781	31.30
22	1.0923	12.20	59	1.2840	31.85
23	1.0968	12.70	60	1.2898	32.40
24	1.1014	13.30	61	1.2958	32.90
25	1.1060	13.80	62	1.3017	33.40
26	1.1107	14.35	63	1.3077	33.90
27	1.1154	14.90	64	1.3138	34.40
28	1.1201	15.40	65	1.3198	34.90
29	1.1248	16.00	66	1.3260	35.40
30	1.1296	16.50	67	1.3322	35.90
31	1.1344	17.10	68	1.3384	36.40
32	1.1393	17.60	69	1.3446	36.90
33	1.1442	18.20	70	1.3509	37.40
34	1.1491	18.70	71	1.3572	37.90
35	1.1541	19.20	72	1.3635	38.30
36	1.1591	19.80	73	1.3699	38.80
37	1.1641	20.30	74	1.3764	39.30

SOURCE: From "Official and Tentative Methods of Analysis," Association of Official Agricultural Chemists.

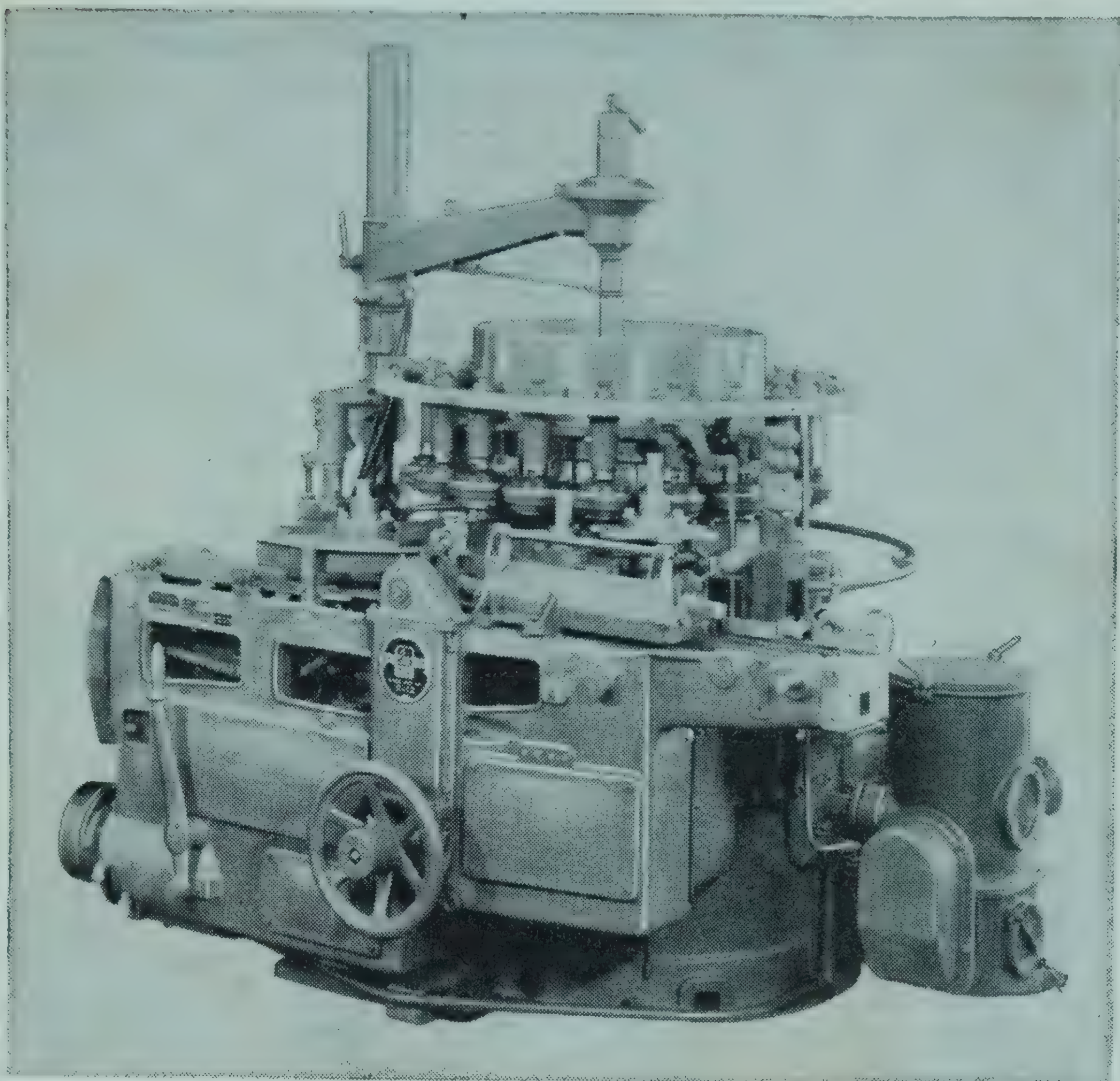


FIG. 21. Prevacuumizing siruper for canned fruits. (*Food Machinery Corp.*)

the hydrometer. The test must be made at this temperature, or suitable correction must be made. Usually the sirups are at much higher temperatures than those at which the instruments are calibrated. At temperatures above the standard the observed reading will be too low, because the higher temperature expands the volume and correspondingly decreases the Brix degree.

In one large California cannery a sample of the hot sirup is passed through a metal coil surrounded by running cold water, which cools it in a few seconds to standard temperature. No correction is then necessary.

The magnitude of the temperature correction for each temperature degree varies somewhat with the sugar content (density) of the sirup and with the temperature range. Thus the average correction per degree centigrade at 20 to 30°C. for a sirup of 30° Brix is 0.08° Brix, whereas in the range 90 to 100°C., it is 0.15° Brix per degree centigrade.

A Fahrenheit temperature-correction table for sirups for Brix degree will be found in "Official and Tentative Methods of Analysis" of the Association of Official Agricultural Chemists, Washington, D.C., together with extensive tables of Brix, Baumé, and specific gravity of sirups at several temperatures (see also Table 10).

For sirups of densities commonly used in canning, viz., 10 to 55° Brix,

TABLE 10. TEMPERATURE-CORRECTION TABLE FOR SUGAR SIRUPS
(Showing actual Balling reading at observed temperature)

Temperature, °F.	Degree of sirup desired									
	10	15	20	25	30	40	50	60	70	75
	Actual saccharimeter reading at temperature observed									
32	10.41	15.52	20.62	25.72	30.82	40.98	51.11	61.22	71.25	76.29
41	10.37	15.44	20.52	25.59	30.65	40.75	50.80	60.88	70.91	75.94
50	10.29	15.33	20.36	25.39	30.42	40.49	50.50	60.54	70.58	75.61
54	10.22	15.24	20.26	25.29	30.31	40.34	50.36	60.40	70.42	75.46
57	10.16	15.17	20.18	25.19	30.21	40.22	50.23	60.26	70.28	75.32
61	10.08	15.19	20.10	25.10	30.11	40.12	50.12	60.14	70.16	75.18
62	10.03	15.03	20.03	25.04	30.04	40.04	50.04	60.05	70.05	75.06
63	10.00	15.00	20.00	25.00	30.00	40.00	50.00	60.00	70.00	75.00
64	9.97	14.97	19.97	24.97	29.97	39.97	49.97	59.97	69.97	74.98
68	9.92	14.91	19.91	24.90	29.90	39.90	49.90	59.90	69.92	74.94
72	9.71	14.69	19.69	24.68	29.68	39.67	49.66	59.68	69.71	74.75
75	9.59	14.57	19.56	24.54	29.54	39.53	49.50	59.54	69.57	74.60
79	9.46	14.44	19.42	24.40	29.39	39.38	49.34	59.38	69.42	74.45
82	9.32	14.30	19.28	24.24	29.24	39.22	49.18	59.22	69.28	74.39
86	9.18	14.13	19.18	24.08	29.06	39.02	49.06	59.12	69.12	74.14
90	9.02	13.91	18.97	23.92	28.92	38.90	48.86	58.90	68.97	74.02
93	8.86	13.84	18.79	23.76	28.76	38.72	48.70	58.74	68.81	73.83
97	8.68	13.67	18.62	23.59	28.59	38.54	48.53	58.58	68.65	73.67
100	8.51	13.49	18.45	23.41	28.41	38.36	48.35	58.40	68.49	73.51
104	8.33	13.29	18.27	23.21	28.21	38.18	48.17	58.22	68.31	73.35
108	8.14	13.11	18.07	23.01	28.01	38.00	47.99	58.04	68.15	73.19
110	8.04	13.01	17.97	22.91	27.91	37.90	47.90	57.95	68.07	73.11
112	7.94	12.99	17.87	22.81	27.81	37.80	47.81	57.86	67.98	73.03
115	7.73	12.70	17.66	22.61	27.61	37.60	47.61	57.68	67.80	72.77
117	7.62	12.59	17.55	22.51	27.51	37.50	47.51	57.59	67.71	72.76
119	7.51	12.48	17.46	22.41	27.41	37.40	47.41	57.50	67.62	72.75
121	7.40	12.37	17.33	22.31	27.31	37.30	47.31	57.40	67.53	72.58
122	7.29	12.26	17.22	22.20	27.20	37.20	47.21	57.30	67.44	72.49
124	7.19	12.16	17.11	22.10	27.10	37.09	47.11	57.20	67.35	72.40
126	7.08	12.06	17.00	21.99	26.99	36.98	47.01	57.10	67.26	72.31
128	6.97	11.96	16.89	21.88	26.88	36.87	46.91	57.00	67.17	72.22
130	6.86	11.85	16.78	21.77	26.77	36.76	46.81	56.90	67.08	72.13
131	6.74	11.74	16.67	21.67	26.67	36.71	46.70	56.80	67.00	72.04
133	6.61	11.61	16.56	21.56	26.56	36.54	46.61	56.70	66.91	71.95
135	6.48	11.48	16.45	21.45	26.45	36.43	46.57	56.60	66.82	71.86
137	6.36	11.36	16.34	21.34	26.34	36.22	46.40	56.56	66.73	71.77
139	6.24	11.24	16.23	21.23	26.23	36.21	46.29	56.40	66.65	71.68
140	6.18	11.12	16.12	21.12	26.12	36.10	46.18	56.30	66.57	71.59
149	5.47	10.46	15.49	20.49	25.51	35.52	45.64	55.79	66.05	71.12
158	4.82	9.80	14.86	19.87	24.90	34.94	45.10	55.68	65.73	70.65
167	4.00	9.10	14.16	19.21	24.26	34.34	44.57	54.73	65.01	70.16
176	3.38	8.61	13.46	18.54	23.62	33.74	43.94	53.61	64.50	69.67
185	2.56	7.62	12.70	17.79	22.90	33.08	43.32	53.18	63.96	69.15
194	1.74	6.84	11.94	17.03	22.15	32.42	42.70	53.04	63.42	68.63
203	0.86	5.98	11.11	16.23	21.39	31.65	42.03	52.41	62.83	68.10
212	0.01	5.13	10.28	15.46	20.61	30.97	41.36	51.78	62.24	67.58

SOURCE: After Wiegand.

the average approximate correction in Brix degrees for each degree Fahrenheit above the standard temperature for which a given hydrometer is calibrated is 0.052° Brix, or for each 10°F. it is 0.52° Brix. Thus a sirup testing 25° Brix at 63°F. would test only 21.12° Brix at 140°F.; or a sirup to test 25° Brix at 63°F. should be made to 21.12° Brix if tested at 140°F. (as is often the case in practice). These relationships are made plain in Table 10, which will be found very useful in the sirup room.

Use of Abbe Refractometer. The Abbe refractometer is very useful for checking the accuracy of hydrometers and for determining the soluble-solids content of the fruit and sirup after canning. It is described in Chapter 16.

Effect of Impurities. Carbonates and sulfates in the water used in preparing sirup may cause white precipitates during boiling. Iron salts in the sugar may cause darkening of the sirup or precipitation in the can. Soft water is therefore preferable to hard water in the preparation of sirups for canning.

Spoiling of Sirups. If the sirup is used during the day upon which it is prepared, there is little danger of spoiling. If, however, the pipes between the sirup tank and the siruping machines are allowed to stand several days unused and uncleaned, enough yeast or bacteria may develop to cause disagreeable flavors, ropiness, or fermentation. On this account sirup lines and tanks should be kept clean and as nearly sterile as possible.

Effect of Composition of the Fruit upon the Balling Degree of Sirup Used. Very sour fruit requires more sugar, i.e., a more concentrated sirup, than fruit of the same variety of lower acid content, in order to produce the same degree of sweetness as judged by taste, and fruit low in soluble solids will require a sirup heavier than normal.

Effect of Fill of Can on Balling Degree of Sirup. A can in which the fruit is packed tightly will require a more concentrated sirup than a loosely filled can, because of the greater ratio of fruit to sirup. Therefore it is sometimes necessary in the packing of soft fruit to increase the Balling degree of the sirup so that the cutout test will be satisfactory. Most commercial canners cut dozens of cans from their daily production in order to maintain the proper Brix degree of sirup.

Siruping Machines. Because exhaust boxes are now seldom used in fruit canneries, having been replaced by steam-flow closing of the filled cans, and because fruits contain considerable gas, it is necessary to treat the cans of fruit under vacuum before sealing. Therefore the modern siruping machine not only adds the required amount of sirup to each can of fruit, but also subjects the can and contents to a high vacuum before it proceeds to the double seamer. Such a siruper is shown in Figure 21.

In the displacement type of siruping machine the can and contents are first automatically drained to remove any water present, and then the

FIG. 22. Flocron dispenser for automatic delivery of measured amount of brine or other liquid to can or jar. Controlled by electric eye. (*Morton Salt Co., Chicago. Manufactured by Magnuson Engineers, San Jose, Calif.*)

sirup is added automatically to a predetermined level. A displacement cup enters each can and is adjustable to give the proper fill of sirup. This type of siruper is accurate and of large capacity.

Another style of siruping machine, in which the cans are filled by passing beneath streams of sirup, has been used in several large canneries. The excess sirup flows into a reservoir beneath the siruper and is returned by rotary pump. In still another siruper, the Judge siruper, a measured volume of heavy sirup is added to each can of fruit. After heat-exhausting, the can is filled with hot water and sealed.

Brines and Brining. Most canneries use dilute brines of 1 to 2 per cent salt content for vegetables, and for peas a dilute brine containing considerable added sugar. Ripe olives are canned in brine containing 2 to 3 per cent salt. However, very often brine as such is not added, but dry salt is added by dispenser or a small pellet of salt is added to each can, and hot water is added to cover the product (Figure 43).

Salt for canning purposes should be at least 99 per cent sodium chloride, NaCl, and that of lower purity than 98 per cent should not be used. Iron

compounds in the salt will cause discoloration of the brine and precipitation in the can, and the iron may combine with the tannin of the vegetables to cause blackening. Calcium salts may cause a white precipitate on boiling or sterilizing and a toughening of the product. Bicarbonate of calcium is transformed by boiling into carbonate and is precipitated as such. The presence of excessive amounts of sodium and magnesium sulfates or other sulfates may give a bitter flavor to vegetables.

For reasons similar to those given for salt, the water for brines should be as pure as possible. In some cases it may be advantageous to boil the brine before use in order to cause coagulation and precipitation of calcium salts and other impurities, and it should be allowed to settle or be filtered before use if a heavy precipitate forms.

Hydrometers for Brines. Two different hydrometers are used in the testing of brines for canning. In the canning of olives, the brine is normally tested by what is known as a "salometer." A brine testing approximately 100° salometer will contain 26 per cent of salt.

The Baumé reading multiplied by 4 corresponds approximately to the salometer reading (see also Table 47). The brine used for corn and peas usually contains a small amount of sugar. The amount of sugar added will vary according to the grade and according to the practice of the cannery but is usually from 3 to 10 per cent (Chapter 10).

Adding Brine or Salt. Because brine is very much cheaper than sirup, the brining machines are often less perfect in design and operation than the siruping machines, often consisting merely of an open pipe from which a stream of brine flows into cans; the cans of vegetables or olives pass on a chain conveyer beneath the brine pipe. The cans are filled to overflowing, and the excess of brine is allowed to flow to the sewer. Many factories at the present time, however, are using the automatic displacement type of siruping machine commonly employed in canning fruit. As previously mentioned, in the canning of ripe olives and some vegetables granular salt or a salt pellet is added by dispenser and hot water is added to fill the can.

Tomato juice is usually salted by automatically adding a pellet or measured volume of salt to each can of juice just before sealing. Canned spinach, asparagus, and some other products are salted in similar manner; i.e., water and salt are added separately to each can.

REFERENCES

Bitting, A. W.: "Appertizing, or the Art of Canning," The Trade Press Room, San Francisco, 1937.

Browne, C. A.: "Handbook of Sugar Analysis," John Wiley & Sons, Inc., New York, 1942.

Campbell, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

JACOBS, M. B.: "Chemistry and Technology of Food and Food Products," Interscience Publishers, Inc., New York, 1951. Chapter on sugars and sirups.

JOSLYN, M. A.: "Food Analysis," Academic Press, Inc., New York, 1950.

———: Use of liquid sugars in the freezing of peaches and apricots, *Food Technol.*, **3**(1), 8–14, January, 1949.

LEWIS, F. A.: Corn sweeteners in food products manufacture, *Western Canner and Packer*, **48**(11), 26–37, October, 1956.

MURRAY, R. V., and PETERSON, G. T.: Water for canning, *Continental Can Co. Research Dept., Bull.* 22, 1951.

Official and Tentative Methods of Agricultural Analysis, *J. Assoc. Offic. Agr. Chemists*, 1954.

"The Role of Sugar in the Food Industry," Holly Sugar Corporation, San Francisco, 1955.

VON LOESECKE, H. W.: "Outline of Food Technology," Reinhold Publishing Corporation, New York, 1942.

"This is Liquid Sugar," Refined Syrups and Sugars, Inc., New York, 1955.

WOODMAN, A. G.: "Food Analysis," McGraw-Hill Book Company, Inc., New York, 1941.

CHAPTER 6

EXHAUST AND VACUUM

As employed in the canning industry, "exhausting" usually signifies heating the can and contents before sealing. It may also mean treatment of the container under a mechanically produced vacuum. In either case it has for its purpose the objects listed below.

Objects of Exhausting. One of the most important objects of exhausting is to remove air from the contents of the can and thereby reduce corrosion of the tin plate, since corrosion is favored by the presence of oxygen.

A second object is to produce a vacuum so that the ends of the can on the grocer's shelf will be concave and thus indicate to the prospective purchaser that it is in sound condition. Convex or bulged ends usually indicate gaseous spoilage.

A third very important purpose of exhausting is to prevent undue strains upon the can during sterilization.

Thorough exhausting by heat tends to prevent overfilling of the can but also permits a greater fill of soft products, such as berries.

Relation of Temperature of Exhausting to Degree of Vacuum. A No. 2½ can of fruit or vegetables should, after sterilization and cooling, show a vacuum of 8 to 15 in. when tested with a can-vacuum testing gauge. The vacuum will vary according to the temperature of the can at time of sealing. The usual exhausting temperature for fruits is 180 to 205°F., this range of temperature referring to the temperature of the exhaust box. The temperature in the center of the can ordinarily reaches 170 to 180°F.

Large cans, such as gallon and No. 10 sizes, if exhausted too thoroughly will become paneled; i.e., the sides of the can will be drawn in, and in certain cases the can may collapse. The No. 2 cans or smaller sizes may usually be exhausted very thoroughly without danger of collapsing.

Magoon and Culpepper have made a study of the relation between the temperatures of the contents of the can and the vacuum in inches after sterilizing and cooling. The authors have calculated the values for the vacuum in inches for a noncontractile receptacle containing air and saturated vapor when sealed at various temperatures and cooled to the uniform temperatures of 0, 10, 20, 30, and 40°C. Cans are not perfectly rigid, noncontractile containers, and to a certain extent the walls may be

FIG. 23. Fork-lift truck loaded with canned pineapple. (*Dole Hawaiian Pineapple Co., Honolulu.*)

drawn inward by the difference in pressure inside and outside the can. To that extent the internal pressure is increased, i.e., the vacuum decreased. As the sealing temperature is increased, the vacuum in the can increases on cooling. Thus cans sealed at 70 and 50°C., respectively, and cooled to 20°C. show about 12.3 and 6 in. vacuum, respectively. The data also show that the temperature of the can at the time of determining the vacuum markedly affects the vacuum reading. Thus a can sealed at 70°C. should show a vacuum of about 12.3 in. when cooled to 20°C., of about 10.9 in. when cooled to 30°C., and 14.3 in. when cooled to 0°C. This relation explains why cans may leave the cannery in apparently good condition and on storage in a hot climate develop slight internal pressure and the appearance of mild "springers," or spoiled cans. It also explains why cans are more liable to collapse during shipment in cold weather; the low temperature increases the vacuum, and hence in effect the atmospheric pressure on the walls of the can.

Cans show less vacuum at high altitudes than at low because of the crease in barometric pressure as the altitude increases. In fact, a can hat shows, for example, 5 in. vacuum at sea level will show a positive ressure and may become a mild springer at 10,000-ft. elevation (for furher discussion of this point see Clark, Shostrom, and Clough).

Magoon and Culpepper have made an experimental study of the effect f sealing temperature on the vacuum in inches in cans of several important anned foods. They have also determined the effect of processing temperaure upon the vacuum.

The data indicate that the higher the temperature of sterilization, the ower the vacuum in the can, a fact probably accounted for by greater volution of gas at the higher temperatures tending to reduce the vacuum expressed in inches of mercury).

Effect of Temperature of Head Space. The temperature of the head pace at time of sealing was found by Magoon and Culpepper to affect

TABLE 11. EFFECT OF TEMPERATURE OF HEAD SPACE, AT SEALING, ON VACUUM

Product	Length of exhaust in steam, min.	Vacuum, in., cans sealed at once	Vacuum, in., head space cooled but solid content not cooled
Tomatoes, No. 2 cans	2	15	
	4	16⅞	
	6	17½	
Tomatoes, No. 3 can	2	15	3½
	4	15	6½
	6	16	
	5	....	8

SOURCE: After Magoon and Culpepper.

the vacuum in a can, as shown by Table 11. The reason for this relationship is twofold; at the higher temperature the air present expands to a greater extent and more of the air is displaced with steam.

Meaning of Vacuum. The vacuum in a can of food is nothing mysterious or difficult to understand; it is merely the difference in pressure between the pressure of the atmosphere inside the can and that outside the can. For example, suppose that the barometric or atmospheric pressure of the outside atmosphere is 29.5 in. and of that inside the can 17 in. The "vacuum" inside the can is then $29.5 - 17 = 12.5$ in. This is the value that would be indicated on the dial of a vacuum gauge used in testing the can.

Thus it can be seen that vacuum in the can is governed not only by t pressure in the can but also by the outside atmospheric pressure.

Disappearance of Oxygen. Analysis of the gaseous contents of unenameled can of food that has stood for a few weeks will show practical complete absence of oxygen. The gas will be found to be principal nitrogen with a small amount of carbon dioxide—unless corrosion has be appreciable, when hydrogen will also be found. The oxygen sealed in t can rapidly combines with the plate and to some extent with the fo product, hence is no longer present as a gas. The internal gaseous pressu is correspondingly decreased; i.e., the vacuum is increased. Since approx mately one-fifth of the atmosphere consists of oxygen, this change in i state may markedly increase the vacuum.

Exhausting and Corrosion. While, as will be pointed out in great detail later, the corrosion of tin plate is to a large extent due to local c action and occurs for the most part in the absence of gaseous oxyge nevertheless the presence of oxygen in the can during and shortly aft processing may intensify initial corrosion of the plate and thus favor su sequent corrosion in the absence of oxygen. At any rate it is a well-demo strated fact that oxygen present in the head space and in the tissues such products as apples and fruit juices when the can is sealed will greatl shorten the life of the canned product by favoring subsequent corrosio with evolution of hydrogen gas or pinholing.

This subject is discussed further in Chapter 11.

Effect of Size of Head Space. Other things being equal, the vacuu in the can after sealing and cooling will vary inversely with the volume the head space at the time of sealing, as will be seen from the followin consideration. If a can is filled completely with the food product at tim of sealing, the head space formed by cooling of the contents after sealin will be filled principally with "nothing"; i.e., there will be practically n permanent gas present and therefore very little pressure, or conversel there will be a very high vacuum. If, on the other hand, there is a larg space at the time of sealing, this space will contain considerable air whic after the can is sealed and cooled, will exert pressure and give a co respondingly lower vacuum.

Determining the Vacuum in Cans. The usual method of determinin the vacuum is by means of a vacuum gauge fitted with a hollow ste point protruding through a heavy soft-rubber gasket. In taking th vacuum of a can, the hollow point is forced through the lid of the ca the rubber gasket making a gastight seal and preventing loss of vacuum The vacuum in inches is indicated by a needle on the dial of the gaug The gauge often is constructed to indicate both pressure and vacuum since cans will often exhibit a "negative" vacuum, i.e., possess a pressu in excess of atmospheric pressure (see Figure 24).

Types of Exhaust Boxes. In the exhausting of fruits the cans and ntents are ordinarily exposed to high temperatures (185 to 205°F.). A ng exhaust at a moderate temperature is to be preferred to a short haust at a high temperature, if one considers only the effects produced ther than efficiency of operation or cost.

The disk exhaust box consists of a rectangular metal box in which are veral rows of large metal disks from 15 to 18 in. in diameter fitted with g gears that mesh together. Above the disks e curved iron rods that guide the cans rough the exhaust box. The cans travel down e row of disks and back the next. Usually e exhaust box contains three to four rows disks. The number of rows, however, and the ngth of the exhaust box vary according to the pacity desired and the nature of the product be exhausted.

FIG. 24. Vacuum gauge for measuring vacuum in cans of food.

Cable Exhaust Box. This simplest type of khaust box consists of a narrow, shallow, ectangular metal container through which asses a steel cable which carries the cans.

In one modification of the cable exhaust box ne cable is replaced by a chain conveyer. One f the objections to the chain or cable exaust box is that the cans sometimes become ammed, causing delay and inconvenience.

A rotary exhaust box, in which the cans re carried through a steam-filled cylinder on reel, has been developed. In many canneries xhaust boxes have been replaced by steam-flow closure or by vacuumlosing machines (see the section on this subject later in this chapter).

Where floor space is limited the circular exhaust box, in which the cans ollow a circular or spiral path in passing through the box, is very desirable.

For products that are pasteurized in the cans below 212°, it may be advisable to pass the filled cans through a shallow tank containing water eated to the desired temperature, e.g., in the canning of citrus fruits.

Exhausting by Mechanical Vacuum. Practically all food products that are sterilized in glass jars are exhausted under a mechanically produced vacuum instead of by heat, and this process has been applied for many years to the canning of coffee in cans, to the exhausting of canned fish and fish products, and to preserves, jellies, etc., in glass. More recently, equipment has been perfected for applying this procedure to many other canned products. It is used to some extent in California for asparagus, peaches, spinach, and other common fruits and vegetables. The pretreatment and

the operation of the vacuum-sealing equipment must be adjusted to suit the product being canned.

Filling Cans with Precooked Product. In the canning of cream-style corn it is customary to cook the product with a small amount of sugar, salt, starch, and water and seal the corn hot before processing. Exhausting in this case is unnecessary. The same is usually true of tomato juice, purée, baby food, sieved pumpkin, and some other fluid products.

Wiegand, of the Oregon Agriculture College, has proved that the same process may be used to advantage in the canning of cider. Orange juice also has been handled in this manner.

Vapor Sealing. Jars using the White Vapo-seal caps and certain other caps are sealed in a current of steam in a special machine. The jar enters a metal box; a jet of steam plays on the top of the jar and contents, expelling most of the air in the head space; a lid falls in place, and the lid is forced on to the jar mechanically. A good vacuum is attained in this manner.

A similar exhausting and closure procedure is now in rather general use for tin containers under the designation of "steam-flow closure," or "steam-vac closure." Its history and present method of application are covered rather fully in the *American Can Co., Research Department, Bulletin* April, 1950, and in the *Continental Can Co., Research Department, Bulletin* 18.

In this process steam is jetted into the head space of the can immediately before and during the assembling of the can and cover, as well as during the double-seaming operations (sealing). When the steam in the head space of the sealed can condenses, a vacuum is formed.

The can companies' engineers found that when the head space was small, almost no vacuum was obtained after sealing and cooling, but that if the head space were relatively large, a good vacuum resulted, provided other conditions were correct. Necessary conditions are that the air must be swept effectively from the head space by the steam flow and that an atmosphere of steam be maintained around the can and cover assembly until the can is sealed against any possibility of air leaking into the can. To be of practical value these operations must be conducted at high speed.

Other requirements are that the food be prepared in such manner that an excessive amount of air or gas is not left in the product to later fill the head space and reduce the vacuum; that the steam can sweep the air out from around the pieces of product that may project into the head space; and that the product is of such nature that the volume of the head space can be controlled.

One serious difficulty with this method is entrainment of air by the steam jet. This has been overcome in the design of present equipment.

The steam-flow attachment is not very complicated, although several years of intensive research and engineering were necessary before a satis-

factory machine and procedure were perfected. The essential parts are a means of introducing a jet of steam into the head space with steam at proper pressure and temperature, and a more or less enclosed chamber in which an atmosphere of steam at high temperature can be maintained during all operations.

The most practical method of adjusting the head space is by "topping," which essentially is done by a plunger located between the siruper or briner and the double seamer (sealer). It is mechanically operated and is adjustable. It forms the desired head space by pushing downward into the contents of the can to a predetermined depth. Some liquid is forced out of the can, and if valuable, can be recovered and filtered for re-use. According to the American Can Company, minimum gross depth of head space that will give a satisfactory vacuum is $^{10}\!/_{32}$ in. Larger head spaces will give greater leeway; however, the canner must not allow such a large head space that it exceeds the maximum permitted by the food and drug regulations.

Steam is in contact with the food so short a time that there is no blanching effect; if blanching is necessary it must be done before canning. Also, because of the very short contact, the steam has no sterilizing effect during steam-flow or steam-vac sealing.

In comparison with exhausting by steam exhaust box a can of food filled cold and sealed by the steam flow or similar procedure will require a slightly longer process time (sterilization) because of its lower initial temperature upon entering the retort or other processing (sterilizing) equipment. This is also true of vacuum-sealed, cold-filled cans of food.

If this method of closure is applied directly to canned fruits, difficulty is encountered because of the air entrapped by and between the pieces of fruit and because topping to secure adequate head space often damages the fruit in the top layer in the can. The best solution to this problem at present appears to be to subject the fruit after canning to a high vacuum followed by releasing of the vacuum with sirup to a predetermined level and then steam-flow or steam-vac closing of the can.[1] This procedure eliminates the very costly vacuum-sealing machine that would otherwise be necessary if the exhaust box were eliminated. It is the method now in use in fruit canneries. A prevacuumizing siruper is shown in Figure 21.

Can manufacturers recommend that at the beginning of operations each day a few cans of water be sealed in the double seamer and the vacuum determined on cooling, in order to make certain that the seamer is in satisfactory operating condition. Occasional checks on the vacuum of sample cans of the product during the day are also recommended.

If the cans are filled hot, as is the case with cream-style corn, tomato

[1] The steam-closure method of the American Can Co. has been named steam-flow closure and that of the Continental Can Co. steam-vac closure.

juice, apple juice, and certain other products, the use of an exhaust box or a vapor seal can sealer is not necessary.

Usually, when the vapor-seal steam-closure method is installed, the cannery's exhaust boxes may be removed, thereby releasing much floor space that can be used for other purposes. Where the steam-closure method is used in place of an exhaust box, there is much less waste steam in the cookroom and less steam is used.

RELATION OF EXHAUSTING TEMPERATURE TO PRESSURE IN CAN DURING PROCESSING

It has long been recognized by canners that cans are subjected to internal pressure because of the expansion of gases and vapors in the can during sterilization and that this pressure is greater when the cans are sealed at relatively low temperatures than when sealed at relatively high temperatures. The relation between the temperature of the contents of the can at the time of sealing and the pressure developed in the sealed can during sterilization at various temperatures has been studied quantitatively by Magoon and Culpepper.

Theoretical Values for Water and Air. These authors have calculated the theoretical values for pressures developed in nonexpansible containers filled with air and sufficient water to give saturation when sealed at various temperatures and processed at 100, 109, 116, and 121°C. (212, 228.2, 240.8, and 249.8°F.), respectively. Their data show that cans sealed at low temperatures develop very high pressure during sterilization and that as a sealing temperature of 100°C. (212°F.) is approached, the pressure developed during sterilization decreases more rapidly than the increase in the temperature of sealing. The pressure increases with the temperature of processing. A can sealed at 80°C. (176°F.) develops about 14 lb. pressure at 109°C. (228.2°F.), about 22.3 lb. at 116°C. (240.8°F.), and about 26.5 lb. pressure at 121°C. (249.8°F.). A can sealed at 50°C. (122°F.) develops at 100°C. (212°F.) about 14.7 lb. and at 121°C. (249.8°F.) about 30.7 lb. pressure.

Experimental Values for Water and Air. In determining the experimental values for water in No. 2 cans, Magoon and Culpepper found that (1) the pressures developed were always below the theoretical; (2) the higher the retort temperature, the greater the variation from the theoretical pressures; (3) the higher the initial temperature, the nearer the theoretical does the pressure during sterilizing come; (4) larger cans show a somewhat greater divergence from the theoretical than the smaller cans; and (5) the smaller the head space, the lower the pressure obtained.

The rapid rise noted during the first few minutes of heating is due to expansion of the air in the can.

Increase in Volume of Can and Buckling. The increase in volume of the can varies with its internal pressure. Large cans sometimes buckle, i.e., become permanently distorted along the head seam, from excessive internal pressure.

Increase in volume of the container causes decrease in pressure, a fact which explains some of the deviation of experimental curves from the theoretical and the sudden drops in pressure shown by some of the experimental curves of Magoon and Culpepper. They have found that the can may increase in volume 5 per cent or more under normal canning operations.

According to Bitting an internal pressure of 30 lb. or more is required to buckle a No. 2 can, about 20 lb. for Nos. 2½ and 3 cans, and about 10 lb. for No. 10 cans made of plate of usual thickness.

Strain on Can. The actual strain on the can during processing can be obtained by subtracting the retort pressure from the pressure in the can. Thus, if the retort is operated at 10 lb. steam pressure and the pressure in the can is 18 lb. per sq. in., the effective pressure or actual strain on the can is 18 minus 10, or 8 lb. per sq. in.

When the steam is turned off, the retort pressure rapidly drops to zero. The can does not cool so rapidly as the retort, and consequently it may remain at or near the original temperature and pressure for a short time. It is for this reason that large cans are often cooled under air pressure in the retort to avoid buckling.

Glass Containers. During processing, some glass containers are not hermetically sealed or are so sealed that slight internal pressure will raise the lids; consequently the jars are not subjected to internal pressure, or at most to only very slight pressure. Some types of glass containers are hermetically sealed, however. The containers of this type are usually filled hot and in addition are exhausted under a mechanical vacuum before sealing, or sealed in an atmosphere of steam, in order to reduce internal pressure to a minimum. During sterilization in steam retorts, air pressure is applied to hold the caps in place (see section on the retorting of glass containers in Chapter 7).

Glass containers sealed hot and allowed to cool develop approximately the theoretical vacuum because the walls do not contract or expand appreciably, as do those of tin containers.

REFERENCES

Boyd, J. M., and Bock, J. H.: Vacuum in canned foods: its significance and its measurement, *Continental Can Co., Research Dept., Bull.* 31, 1952.

———, Heinen, J. M., and Parrin, F. W.: Engineering air removal from canned foods, *Continental Can Co., Research Dept., Bull.* 29, 1952.

BITTING, A. W.: "Appertizing, or the Art of Canning," The Trade Press Room, San Francisco, 1937.

———: Exhaust and vacuum, *Natl. Canners Assoc., Research Lab., Bull.* 8, 1916.

CLARK, E. D., SHOSTROM, O. E., and CLOUGH, R. W.: The function of vacuum in canned salmon, *Natl. Canners Assoc. Bull.* (Northwest Branch) 1923.

CHAMELLAN, P., and CHEFTEL, H.: La pression intérieure dans les boîtes de conserves, *Lab. des recherches biol., Bull.* 3, Paris, 1932.

JACOBS, M. B.: "The Chemistry and Technology of Food and Food Products," vol. 2, chap. 1, Interscience Publishers, Inc., New York, 1944 (revised 1951).

MAGOON, C. A., and CULPEPPER, C. W.: Relation of initial temperature to pressure, vacuum, and temperature changes in the container during canning operations, *U.S. Dept. Agr. Bull.* 1022, 1922.

National Canners Association: "Best Service from Food Cans," Can Manufacturers' Institute, Washington, D.C., 1951.

PETERSON, G. T.: Methods of producing vacuum in cans, *Continental Can Co., Research Dept., Bull.* 18, 1949.

Steam-flow closure, *American Can Co., Research Dept., Bull.* 16, pp. 61–64, April, 1950.

CHAPTER 7

PROCESSING OF CANNED FRUITS AND VEGETABLES

"Processing," i.e., heating or sterilization of canned foods, is the most important operation in canning. "Sterilization" is used here in a qualified manner, for as pointed out in Chapter 11, the canned product often is not sterile in a bacteriological sense because of the presence of heat-resistant aerobes or thermophiles that do not develop in the canned product because of unfavorable conditions. The word "processing" is therefore preferable to the word "sterilization" in this connection. Its principal purposes are (1) to render the product stable against spoilage by microorganisms and (2) to improve the texture, flavor, and appearance by cooking. The former is the more important objective. Although processing should be thorough enough to ensure good keeping quality, it is desirable with many canned fruits and vegetables that this objective be accomplished in as short a period as possible so that the product will not be overcooked and thereby injured in flavor and texture. Because of many serious losses of canned fruits and vegetables in the past through insufficient sterilization, canners at the present time are inclined to overprocess their products. An excellent historical review of processing was prepared by Ball, 1938 (see reference at end of this chapter).

PRINCIPLES OF PROCESSING

The fundamental principles of processing have been very thoroughly investigated in the Research Laboratories of the National Canners Association at Washington, D.C., San Francisco, and Seattle, under the direction of W. D. Bigelow, E. J. Cameron, E. D. Clark, I. I. Somers, C. Townsend, and J. R. Esty; by Magoon and Culpepper in the Bureau of Plant Industry of the U.S.D.A.; by Dickson of Stanford Medical School; Meyer of the University of California Medical School; Ball and others of American Can Company; Thompson of Iowa; Rosenau of Harvard; Ford and Parcell of the Glass Container Association and University of California; the research staff of Continental Can Company; and others.

Time and Temperature. In the processing of canned foods both time and temperature are important, since as the temperature increases, the

sterilizing effect is rapidly increased: thus sterilization at 250°F. is approximately 100 times as rapid as at 212°F. Therefore in specifying temperatures for different products it is essential to specify the time also.

Effect of Condition of Raw Material on Sterilizing. The experience of canners has proved that fruits or vegetables which contain a large per cent of moldy or otherwise decomposing raw material are very much more difficult to sterilize than the same products in a sound condition. Overripe fruit, because of the fact that it softens and forms a compact mass in the can and retards heat penetration, is more difficult to sterilize than fruit of firmer texture, which retains its normal shape and texture. Also, its low acidity makes sterilization more difficult. The blanching of fruits or vegetables in boiling water or steam before canning removes some of the microorganisms from the surface of the raw products and in this way reduces their tendency to spoil. It has been proved, however, that blanching of vegetables does not materially reduce the death temperature of resistant spore-bearing organisms, and it is probable that its principal benefit, as it affects sterilization, lies in removal of some of the microorganisms rather than in any sterilizing effect.

Modes of Heat Transference. Heat is transferred from the processor to the canned product by two important means, conduction and convection. The conduction of heat may be described as the transfer of heat between adjacent molecules.

There are wide variations in the conductivity of various materials. Iron, for example, is known as a good conductor, and when one end of an iron rod is held in a flame, the opposite end will, in time, rise in temperature. Wood is known as a very poor conductor.

The transfer of heat in products containing sirup or brine is principally by convection, or transfer of heat by currents set up in the liquid. Heated liquids tend to expand, thereby decreasing in density, a condition that causes them to rise.

Transfer of heat by conduction is very much slower than by convection. Therefore pasty or semisolid products, in which convection currents are sluggish or absent, require very long periods of sterilization. Examples are corn, pumpkin, and sweet potatoes. On the other hand, products that are suspended in brine or sirup heat very rapidly and, other conditions being equal, require a very much shorter period of sterilization than semisolid products. Examples of canned foods in which convection is the principal means of heat transfer are all varieties of fruits, canned peas, and string beans.

Typical Heat-penetration Curve. The rate of heat penetration in canning is usually determined by the temperature at the center of the can, although under some conditions slowest heating may be located elsewhere. If a thermometer is inserted in the center of the can of food and the can is

supported in a sterilizer which is at constant temperature, three distinct periods will be noted. During the first stage of the heating process, the center of the can rises in temperature very slowly, in spite of the fact that during this interval heat units are entering the can at a much higher rate than later in the sterilizing process. During the first stage the material near the outside of the can, however, absorbs nearly all the heat that enters the can, and therefore the heat does not reach the center of the can. During the second period the contents of the can near the sides and ends

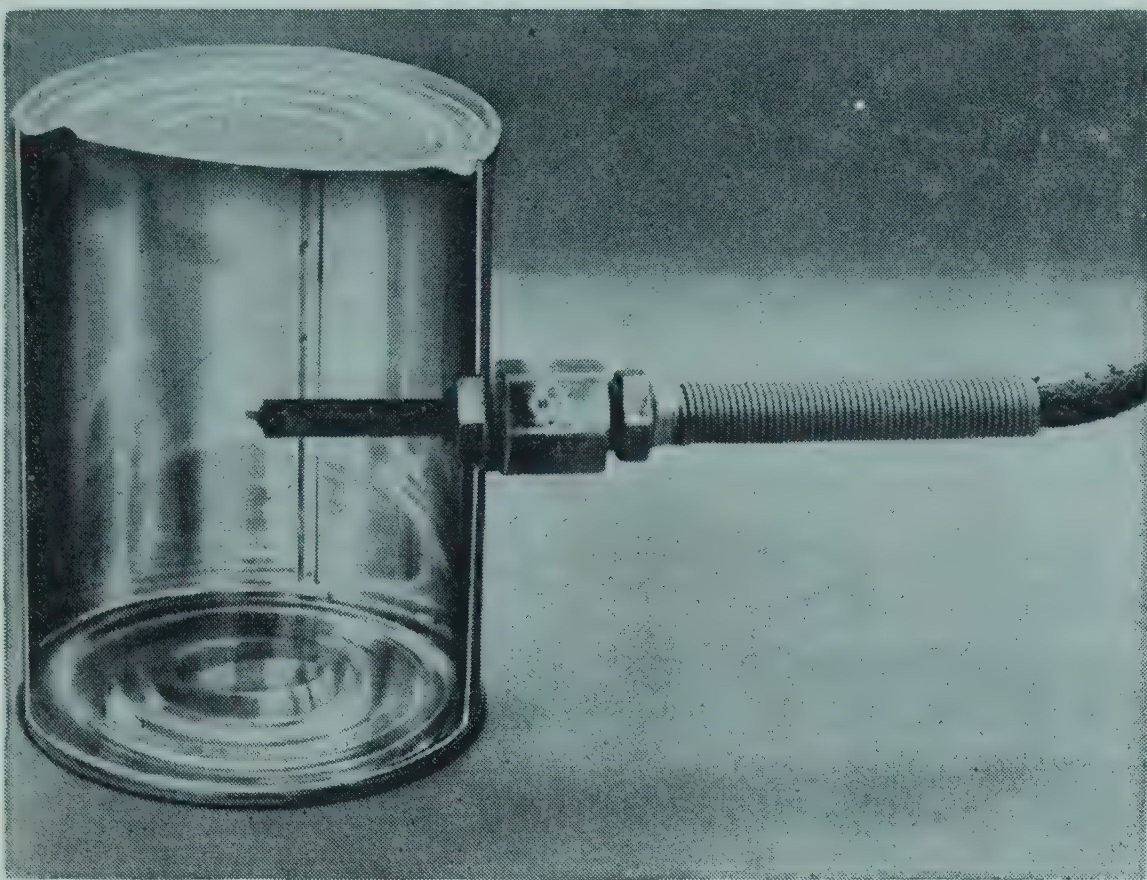


FIG. 25. A cutaway can showing how thermocouple is fitted for rate of heat-penetration measurements. (*American Can Co.*)

have reached a high temperature, and the temperature at the center of the can rises more rapidly. In the third stage of the heating process the contents of the whole can have approached the temperature of the sterilizer, the temperature gradient has become very low, and heat enters the can slowly. These conditions are shown graphically in Figure 27.

Temperature-measuring Devices. Nearly all commercially operated steam-pressure retorts are equipped with automatic temperature-recording thermometers. This style of thermometer ordinarily consists of a long, vapor-filled metallic tube at one end of which is a bulb inserted into the retort and at the other end of which are a dial and an ink-filled stylus. The vapor-filled instrument has largely displaced the mercury-filled one formerly used, because the mercury-filled tube is subject to changes in temperature of atmosphere outside the processor and consequently often gives erroneous readings. For further discussion see the section on temperature control and recording.

The "telltale" thermometer is very generally used by canners. It consists of a small maximum thermometer that operates in the same manner as a clinical thermometer. It is generally attached to a removable screw cap and is protected by a metal sheath. Readings obtained by this style of thermometer are liable to be very inaccurate, since the metal cap and sheath conduct heat rapidly. A more satisfactory method of using the telltale thermometer is to attach it to a small piece of wood in such a manner that the bulb of the thermometer rests in the center of the can or at some other desired level. Cans containing telltale thermometers may be placed at various points in the sterilizer, and a fairly accurate comparison of the temperatures obtained. The cans, however, must be removed and opened for reading the thermometers.

Resistance thermometers have also been used successfully. The resistance unit consists of a small coil of platinum wire wound on a porcelain tube and placed in the can. It is connected to a Wheatstone bridge circuit. Resistance of the wire varies directly with the temperature.

A more convenient temperature-recording device is the thermocouple, which is made of very small copper and constantan alloy wires soldered together. The differences in potential generated at the point of contact of the two metals vary with the temperature. The opposite ends of the wires are kept at a constant temperature by immersion in a mixture of ice and water at 0°C., or a compensating potentiometer is used.

The electromotive force developed is measured by a potentiometer that can be calibrated by immersing the thermocouple in water at known temperatures, e.g., in boiling water and in melting ice. This method of determining the rate of heat penetration in canned goods has been highly developed at laboratories, particularly those of the National Canners, the Glass Container Association, and the American Can Company. With a set of thermocouples it is possible to determine the temperature of cans in an experimental agitating cooker or in commercial sterilizers in which the cans are not agitated. As many as 20 cans may be tested simultaneously with this outfit. Instrument companies can supply the necessary standard wires, such as copper and constantan or other suitable alloy, together with a compensating cold-junction potentiometer calibrated to read temperature directly. The method of assembly is described by Parcell or may be had from instrument companies or can-manufacturing companies. The assembly has been fully described by Ecklund (1949).

Magoon and Culpepper make the point that the thermocouple is not an accurate heat-measuring device because of the high conductivity of the wires as compared with the conductivity of most foods. They state further that a glass thermometer is to be preferred to the thermocouple because of the low heat conductivity of glass. It is probable, however, that the small wires used in the thermocouple are at approximately the same temperature

as the canned food with which they are in immediate contact and that little heat is conducted by the wires themselves to the junction of the two metals. The metal tube covering or sheath for the wires used by Bigelow and associates, however, was found to conduct considerable heat to the centers of the cans, and at the suggestion of Parcell and Ford the couples are now covered with bakelite or some other poor conductor of heat.

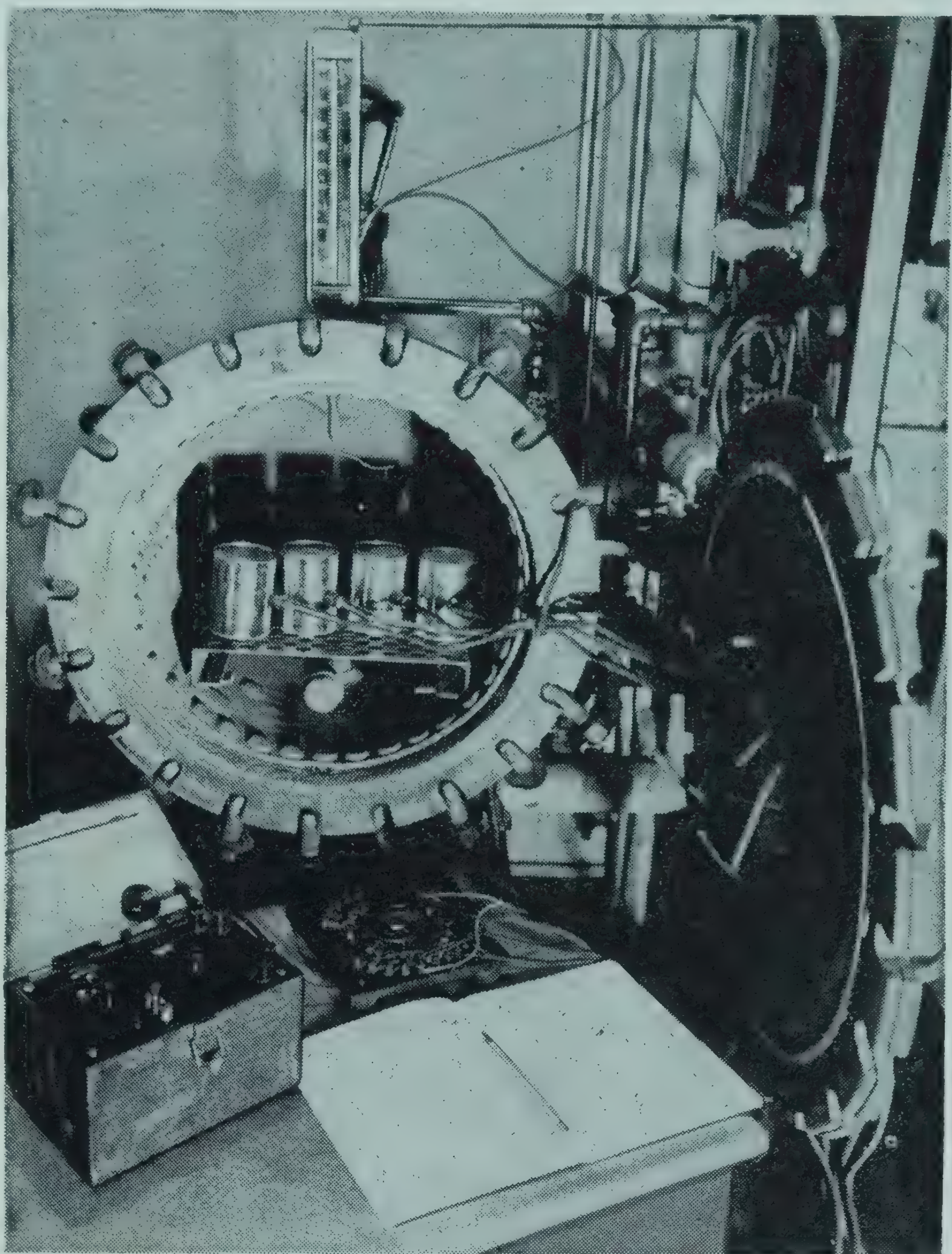


FIG. 26. Filled cans with thermocouple leads brought through retort door. (*American Can Co.*)

Experimental Retorts. Magoon and Culpepper used a small retort, described by them in *U.S. Department of Agriculture Bulletin* 956. This retort proved very useful in obtaining fundamental data on heat penetration. Owing to the small size of the retort, equilibrium at any steam pressure desired may be obtained in 10 to 30 sec.

Bigelow and his associates used a small retort in which it was possible to measure the heat penetration by means of a thermocouple in a can that is rotated during heating. It is described fully in *National Canners Association, Research Laboratory, Bulletin* 16-L, 1921.

For death-temperature studies the National Canners Association and other laboratories now use batteries of six or more very small retorts connected by quick-acting valves to a large reservoir of high-pressure steam and to a cold-water supply. They rise almost instantly to processing temperature and can be very rapidly cooled. Special T.D.T. (thermal-death-time) cans of very shallow depth or small Pyrex tubes are used.

Parcell and others have made use of a commercial-size retort in which heat penetration is measured by thermocouples under industrial conditions. The American Can Company and National Canners Association have used a special small agitating retort in which the temperature in the cans can be measured at regular intervals by thermocouples. In addition, they and other canning research laboratories make use of several non-agitating retorts, equipped with thermocouples, so that as many as 20 containers can be followed simultaneously (see Figures 25 and 26).

Effect of Composition of Container on the Rate of Heat Penetration. The two materials used for containers in the canning of foods are tin plate and glass. Glass is a poorer conductor than iron, the principal constituent of tin plate. Water, the principal constituent of fruits and vegetables, is a poor conductor of heat when convection is prevented, although where convection currents are possible, it heats very rapidly by convection. If convection currents are prevented, as is the case in pasty products, such as corn, or semisolid products, such as pumpkin and spinach, heat penetration is extremely slow and approaches the theoretical minimum penetration for water.

The conducting power of any product may be expressed in terms of "diffusivity," which may be defined as *the temperature change produced in a unit cube of material in a unit time by a unit quantity of heat conducted across a unit area of the product per unit difference in temperature*. Diffusivity is constant for any given material.

The diffusivity constant for glass is 0.37, for water 0.084, and for iron 10.8. From this it can be seen that the rate of heat conductance through glass is about one-thirtieth as rapid as through iron or tin plate but 4.4 times as rapid as through water.

Iron or tin plate transfers heat by conductance 120 times as rapidly as water. This fact explains the very slow heat conductance of cream-style corn, pumpkin, and sweet potatoes, which are essentially water in composition, but of such consistency that convection currents are almost eliminated. Where convection currents are active, iron will heat only four to eight times as rapidly as water, and under similar conditions water in a glass container will heat approximately as rapidly as the glass of the container.

Bigelow found that in tin, olives reached the temperature of the retort in approximately 10 min.; in glass, the time required was approximately

20 min. In the sterilization of some foods, therefore, it is necessary to take into account the slower penetration of heat in glass than in tin.

Effect of Sugar and Salt on Heat Penetration. Salt, sugar, and other crystalloids in dilute solution do not greatly affect the rate of heat penetration. The retarding effect of the salt concentration in the brines normally used in canning is so small as to be negligible. Very heavy sugar sirups, however, may appreciably slow up heat penetration. This fact was proved by Bigelow's investigations in which the center of the can reached the temperature of the retort in about 6 min., where the product was canned in water. In a 50° Balling sirup, 24 min. was required for the center of the can to reach the temperature of the retort. In a sirup of 10° Balling, approximately 7 min. was required, and in a 20° Balling sirup, approximately 9 min. Irish, Joslyn, and Parcell correlated the viscosity of sugar solutions with rate of heat penetration and found a very sharp decrease in the rate at about 60° Balling.

The dissolved sugar increases the viscosity of the liquid and thereby retards convection currents. The retarding effect, however, is not serious at the concentrations used in canning.

Effect of Colloids on Heat Penetration. It has long been observed that starchy food, such as corn, conducts heat very slowly, and experiments by Bigelow, Magoon, and Culpepper and others have proved that starch is the retarding agent. Bigelow found that the rate of penetration was retarded in proportion to the concentration of starch in solution until a concentration of 6 per cent was reached. Concentrations of starch in excess of 6 per cent had approximately the same retarding effect as the 6 per cent solution. At 6 per cent concentration of starch, the rate of heat penetration approaches very closely the theoretical rate of heat penetration for pure water, where convection currents are eliminated. This undoubtedly explains the observed fact that concentrations of starch in excess of 6 per cent have approximately the same retarding effect on heat penetration as the 6 per cent solution. Pectin in solution in jellies and fruit sirups greatly retards heat penetration, as do other viscous colloids.

Effect of Consistency on Heat Penetration. A tightly packed can of fruit or of vegetables heats very much more slowly than a loosely packed can. For example, it was shown by Bigelow that a No. 3 can of spinach reached the temperature of the retort in 6 min. at 220°F. where the can contained only 18 oz. of spinach and that 46 min. was required where the can contained 27 oz. of spinach.

In commercial products it is customary to pack blanched spinach into the cans very much less compactly than formerly. Pumpkin and sweet potatoes are packed in cans in practically a solid condition.

Effect of Size of Container. A longer period of sterilization is required for a No. 10 can of food than for a No. 1 can, for the reason that the distance

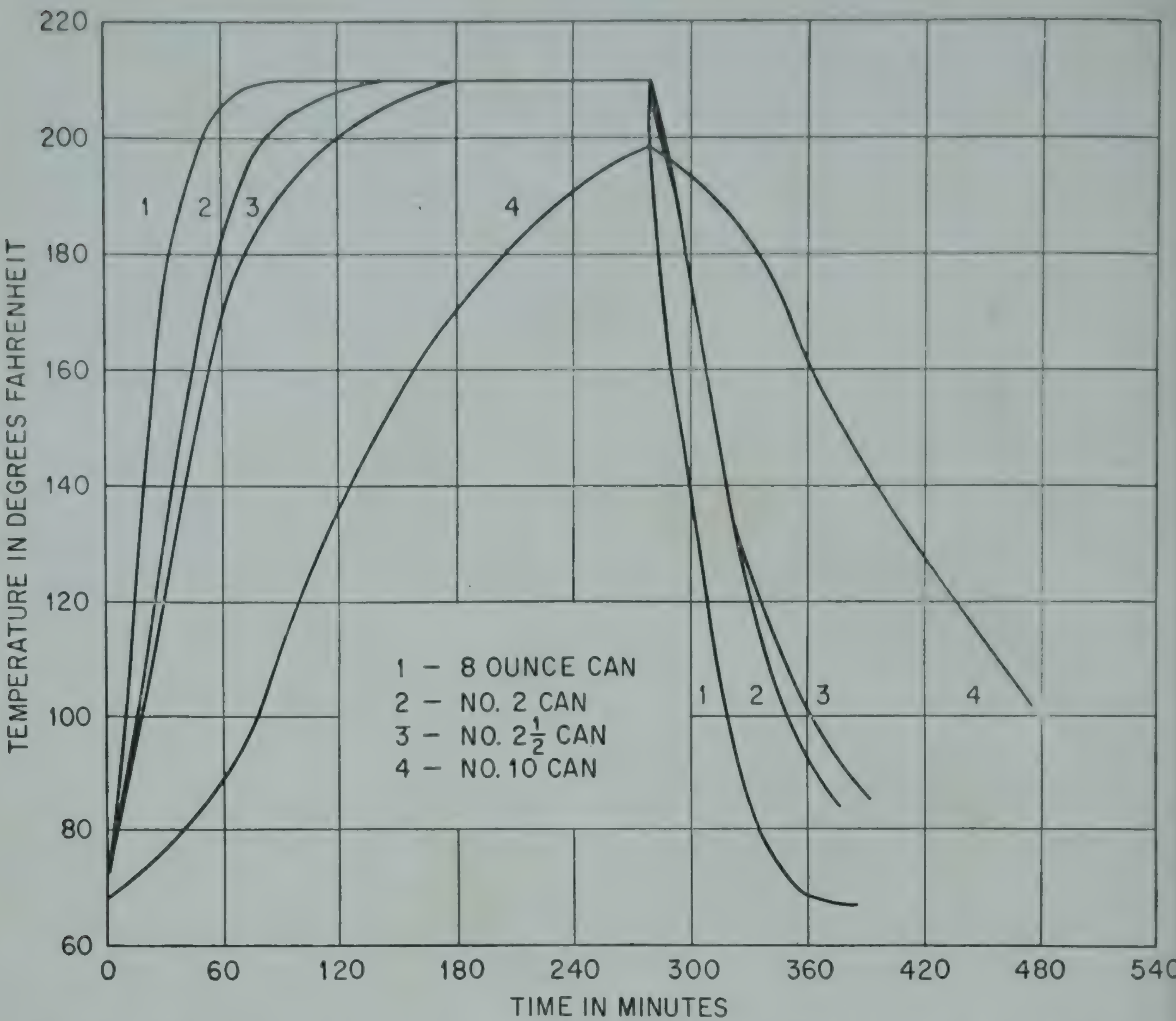


FIG. 27. Effect of size of can on heat penetration at 212°F. (*After Mrak and Cruess.*)

from the surface of a larger can to the center is greater than in the smaller container and because the ratio of surface to volume is larger in the smaller container.

A No. 1 can contains 11½ fl. oz., and its surface is 45 sq. in. The ratio of surface to volume s/v equals 3.9. A No. 10 can contains 107 fl. oz., it has 175 sq. in. of surface, and s/v equals 1.6. It can therefore be seen that the smaller can has a much larger surface exposed per cubic inch of volume. Bigelow and Thompson have determined the effect of the size of the container on the rate of heat penetration and have published tables of factors that show the relative rates of penetration. These factors, however, apply only to cases in which convection currents are not active, e.g., in the sterilization of corn, sweet potatoes and pumpkin, meats, tightly packed spinach, etc.

The time required for heat to penetrate to the centers of cans of similar form but of different sizes varies approximately with the square of the radii. Thus, if it requires 60 min. for the center of a No. 2 can of corn to heat to

240°F. and the time required for a No. 10 can is desired, the following relations would hold:

$$r \text{ No. } 2 = 1.72 \text{ in.} \qquad (r \text{ No. } 2)^2 = 2.96$$
$$r \text{ No. } 10 = 3.1 \text{ in.} \qquad (r \text{ No. } 10)^2 = 9.61$$

The time required for the center of the No. 10 can to reach 240°F. is then obtained by use of the formula $\frac{(r\ 10)^2}{(r\ 2)^2} \times t_2$, that is, by the calculation $\frac{9.61}{2.96} \times 60 = 194$ min. However, this relationship is only approximate and should not be used in commercial-process calculations.

Table 12 gives the factors for relative rates of heat penetration of the more common sizes of sanitary cans.

TABLE 12. HEAT-PENETRATION FACTORS FOR VARIOUS SIZES OF CANS

Size of can	Factor for determining approximate time for cans of specified size				
	No. 1	No. 2	No. 2½	No. 3	No. 10
No. 1	1.00	1.70	2.30	2.50	5.4
No. 2	0.60	1.00	1.40	1.50	3.2
No. 2½	0.44	0.74	1.00	1.10	2.4
No. 3	0.41	0.68	0.90	1.00	2.2
No. 10	0.19	0.31	0.42	0.46	1.0

SOURCE: After Bigelow.

Influence of Rotation. It has been proved in commercial practice that agitating cookers are much more effective than cookers in which the cans are not agitated during sterilization. Rotation or agitation of the can mixes the contents and sets up currents that rapidly transfer the heat.

Most of the open processors now used in the commercial canning of fruits are of the agitating type, the cans rotating approximately 11 r.p.m. This rate of rotation is satisfactory for products consisting of large pieces, such as fruits and tomatoes. As the can rotates the large halves of peaches or large pieces of tomatoes fall through the liquid and set up currents. In this case the cans rotate around their longitudinal axis. In another type they rotate in an end-over-end manner around the shorter axis.

For products of small size, such as peas and corn, the rate of rotation must be greater in order that the contents of the can be set in rapid motion. This fact is shown in a very striking manner in one of Bigelow's experiments, in which it required more than 90 min. for a can of corn to reach the temperature of the retort when the can was not rotated, 70 min. at 10 r.p.m., about 50 min. at 26 r.p.m., about 15 min. at 66 r.p.m., and about 10

min. at 110 r.p.m. It has been found that rotation of the can permits the use of very much higher temperatures for such products as corn.

The discontinuous agitating retort has long been used in the sterilizing of canned milk, where it is necessary to keep a can in motion to prevent scorching of the contents. Continuous agitating pressure sterilizers have now been perfected and are in use for meat products, corn, spinach, and other products, including fruits and milk. They justify their cost by greatly shortening and simplifying the process of sterilization. This subject is given further attention in Chapters 9 to 11 (see Figure 33).

Effect of Initial Temperature of the Contents of the Container. The sterilizing value of the retort is markedly affected by the temperature of the contents of the can at the beginning of sterilization. For example, if a can of corn is placed in the retort at 70°F. and another is heated to 160°F. before it enters the retort, it will be found that with the retort operated at 250°F., if the first can will reach the temperature of 240°F. at the end of 80 min., the can that entered at 160°F. will reach the temperature of 240°F. in about 40 min. Therefore the center of the first can will receive practically no sterilization at 240°F., whereas that of the second can will receive a sterilization of 40 min. at or above 240°. This fact is of very great practical importance in the sterilization of products that conduct heat slowly.

Thorough exhausting of the can and contents in steam, or the packing of the product in the cans hot, is a very material aid to the sterilization of canned foods that conduct heat poorly. If the time required for a can heated to a certain temperature before entering the retort is known, the rate of heat penetration in a similar can heated to a different temperature before entering the retort can be calculated approximately. The following example will make this point clearer.

Given a retort operated at 240°F. Can No. 1 enters the retort at 184°F. and reaches a temperature of 226°F. in 60 min. A second can enters the retort at 90°F. The difference in temperature between can No. 1 and the retort temperature is 56°F.; between can No. 2 and the retort, 150°F. The rate of heat penetration in the two cans will be proportional to the temperature gradient between the sterilizer and the can; in other words, the ratio of heat penetration in the two cans will be 56:150. Therefore, in order to reach the retort temperature in the same length of time, can No. 2 must heat $^{150}/_{56}$ times as rapidly as can No. 1. Thus, at the end of 60 min., if can No. 1 is at 226°F., it has risen 226 minus 184, or 42°F. Can No. 2 will rise in the same time, $^{150}/_{56} \times 42 = 112.5$°F. Its temperature will then be 90 plus 112.5°F., or 202.5°F.

Bigelow and his colleagues experimentally checked similar calculations and found them to hold reasonably well for products that conduct heat slowly. However, such calculations are not a safe guide for practical operating conditions.

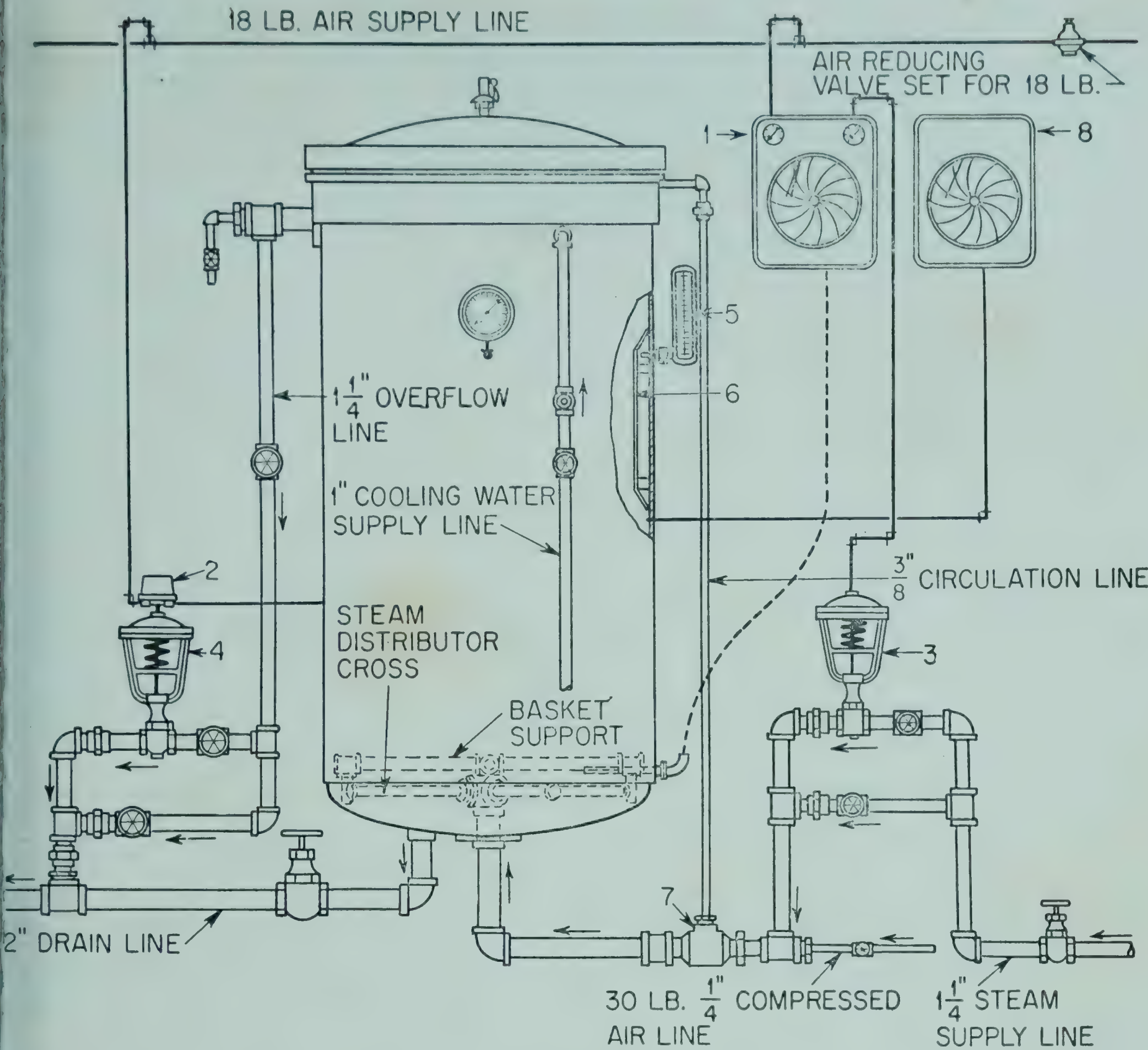


FIG. 28. Temperature-regulating equipment and recording thermometer on a vertical retort. (*Taylor Instrument Co., Rochester, N.Y.*)

Effect of Temperature of Sterilizer. The higher the retort temperature, the more rapid the rate of heat penetration, because of the greater temperature gradient between retort and can. Theoretically, a can of corn in a retort at 240°F. will reach the temperature of the retort in the same length of time as a can in a retort at any other temperature, for example, 250°F. In other words, the time required for the can to reach the final retort temperature will be the same regardless of the retort temperature. However, the can in the retort at 250°F. will reach a temperature of 240°F. in a very much shorter time than a can in the retort held at 240°F. Similar considerations hold for other temperatures.

Influence of Cooling on Processing. The rate of cooling after sterilization affects the processing of canned goods. A can of food that is to be cooled quickly to room temperature after sterilization will require a longer period of processing, other things being equal, than a can cooled slowly, because of the longer period at a sterilizing temperature of the uncooled can.

The increase in temperature during processing and decrease during cooling after processing are governed by the same physical laws. During heating the heat travels from the outside inward and is carried by conduction or convection, or both. In cooling, the same modes of heat transfer are active, but the heat is traveling outward. Theoretically, if a can of food is processed until retort temperature is reached and is transferred to water maintained at the initial temperature of the can, the temperature will follow a curve that is the reverse of the heating curve. Practically, this is not true because of changes in the physical condition of the product during processing: the sirup may become more viscous and thus impede heat transfer, or other changes may occur.

Air cooling is much slower than water cooling because of the lower heat-carrying capacity of air.

Comparative Value of Steam and Water as Heating Media. Some canners contend that water is a much more effective heating medium than live steam. However, cans in live steam are soon covered with a film of water, and this film is probably as effective as a larger volume of water in conducting heat to the can.

Bigelow and others have made numerous experiments to determine the relative heating value of steam and water and have concluded that both are equally effective, provided the source of steam is adequate. However, the presence of air in the steam will greatly reduce its heating value, and therefore the retort should be thoroughly vented during the "coming-up" period, in order to remove as much of the air as possible. See also section on retort operation.

Theoretical and Practical Processing Times. C. O. Ball (*University of California Public Health Department Special Bulletin*) has presented in a very comprehensive manner the theory of processing, particularly the calculation of processing time at any given temperature when such basic data as death temperature of the organism concerned and rate of heat penetration are known. Olson and Stevens, Schultz and Olson, Townsend et al., Williams, and others have published very useful papers on it.

Until relatively recent times the only method of determining processing temperature and time was by the cut-and-try procedure. With modern research on heat penetration and death temperatures of spores of the various bacteria concerned in the spoilage of nonacid canned foods, it has become possible to establish safe processing procedure on the basis of such data. The classic work of K. F. Meyer, J. R. Esty, E. C. Dickson, and their associates on *Clostridium botulinum* (see references at end of Chapter 11) and that of J. R. Esty, E. J. Cameron, and others of the National Canners Association research staff on spoilage bacteria, together with publication of heat-penetration data by various investigators, have laid an excellent foundation for the establishment of processing conditions for various food

products. Also, these data form the basis for theoretical considerations, such as those of Ball, who indicates the following procedure in obtaining theoretical process values. See also Ball and Olson (1957).

First, the organism responsible for the observed spoilage is isolated, and its death times at various temperatures are determined by heating the organism (usually its spores) suspended in a medium as nearly as possible like that provided by the food itself. Small glass tubes or very shallow T.D.T. cans, in which the contents reach processing temperature very quickly, are used. The data are then plotted as a thermal-death-time curve.

Secondly, the rate of heat penetration to the slowest heating point in the cans of the food and the rate of cooling are determined, usually by thermocouples and a potentiometer. These data are also plotted.

Third, by means of the mathematical treatment given by Ball, the theoretical process time at a given temperature is calculated. A working knowledge of higher mathematics is required, as the calculations become complex and involved; for this reason those readers interested in the mathematical treatment are referred to the publication cited.

Heat-penetration curves possess a logarithmic property. In other words, if time in minutes is plotted against the logarithm of temperature of the center of the can, a straight line is obtained, except during the lag period, i.e., the initial stage of the heating curve.

For a curve plotted in nonlogarithmic coordinates, the slope of the curve at any given point is the rate of temperature change at that point and may be obtained graphically by constructing a tangent at that point.

Also, if the time necessary to kill the heat-resistant spores of a given spoilage organism is plotted on semilog paper, against temperature, a straight line is obtained. Therefore, if the death times are determined at a sufficient number of temperatures to establish the curve, the death times required at other temperatures can be read from the curve. Such a curve is shown in Figure 29.

From the curve it can be seen that the death time to kill the spores at 212°F. is nearly 400 min. and at 240°F. about 10 min. For 250°F. the death time reported by Esty and Meyer as shown on the curve is 2.78 min. This is the F value in this instance.

While the data given in the curve apply directly only to laboratory conditions, they are useful in judging the relative rates of sterilization at various temperature for *Cl. botulinum*.

Thermal-death-time Measurements. As mentioned in a previous section of this chapter, equipment has been developed for rapid measurement of the death times of spores of spoilage bacteria at various temperatures.

In one procedure standard Pyrex glass tubes of identical size and rather narrow diameter, containing the sterilized culture medium, which may be standard phosphate buffer or the juice or extract of the food product under

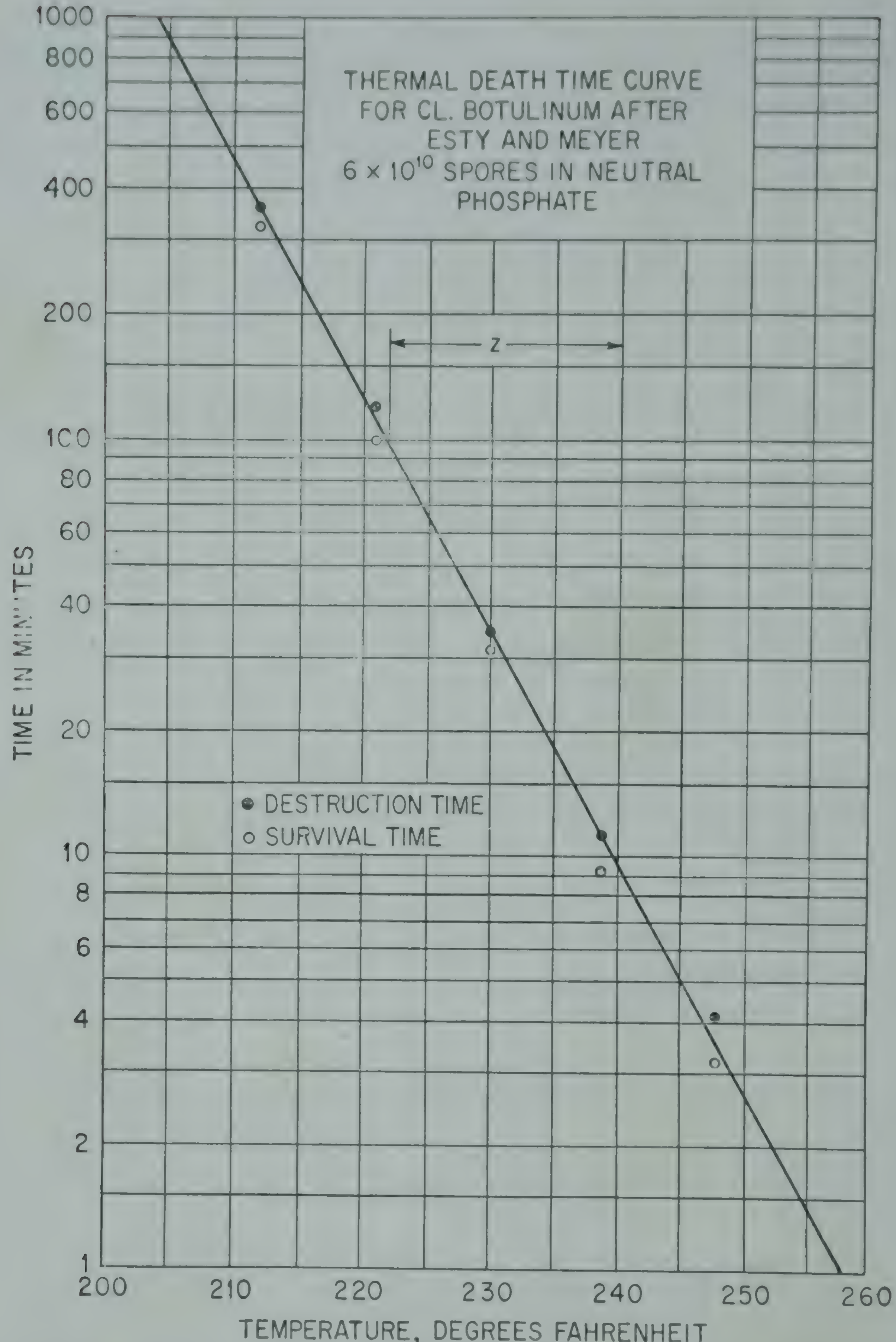


FIG. 29. Typical thermal-death-time curve for *Clostridium botulinum* in neutral phosphate solution. (*From data of Esty and Meyer.*) Points below line represent survival times; those on or above, death times. (*American Can Co.*)

study, are inoculated with a known number of spores and the tubes sealed in an oxygen-gas or oxygen-hydrogen flame. The vegetative cells are destroyed in the culture previously by heating so that spores only remain. The tubes are then immersed in an electrically heated oil bath maintained at constant temperature. As the tubes have been sealed, temperatures above 212°F. can be used. Usually 25 to 30 tubes should be used for each

time of heating at a given temperature. The tubes on removal are cooled very rapidly in ice water and held under refrigeration until they are opened and cultured to test for sterility. This rather large number of tubes appears to be necessary because of skips, such as survival of the spores in one tube in a set heated at a temperature that would be expected to sterilize all the tubes.

In a method devised by Williams, Merrill, and Cameron, a rather large volume of medium is inoculated and heated in an autoclave under pressure in such a manner that samples may be removed aseptically at various time intervals for culturing for sterility.

A very convenient, as well as accurate, method is that described by Townsend, Esty, and Baselt, in which the inoculated culture medium or food juice or extract is placed in a small can of very shallow depth, the can sealed under vacuum and autoclaved in a very small, special retort. The can is $2\frac{1}{2}$ in. in diameter and only $\frac{3}{8}$ in. in depth, outside dimensions. In can manufacturers' terminology it is a 208×006 size can. The maximum capacity of the can is 16 cc., but not more than 13 cc. of medium is placed in it. After heating and cooling, the cans are incubated. Growth is usually evidenced by swelling of the can if a gas-forming organism is used, or by souring of the contents if a flat-sour thermophile is used.

Usually six or more of the very small retorts are used. They are connected to a large retort with automatic temperature recorder and controller. The large retort supplies steam at constant temperature and pressure to the small retorts. Each has a steam "blowoff" exhaust valve at the top and three valves on the bottom for steam, drainage, and cold water, respectively. Two of the retorts are equipped with mercury thermometers. As the steam line is of rather large diameter the small retorts heat very rapidly, a retort "come-up" time of 20 sec. being allowed. Measurements indicate that the contents of the cans reach retort temperature in less than 30 sec. This is slightly less time than for the glass tubes previously mentioned. By use of this procedure and multiple retort setup a great many runs can be made in a day.

Variability in Heat Resistance of Spores. Esty and Meyer and other investigators of *Cl. botulinum* found that the method of growing the cultures greatly affected the heat resistance of the spores. They found also that young, moist spores had greater resistance than older spores and that resistance gradually decreased with age. Weiss observed that one-month-old spores had about three times the heat resistance of the five-months-old spores.

It has been found that spores produced in the laboratory are frequently less resistant to heat than those of the same organism occurring in nature. Consequently, this finding introduces one more factor of uncertainty in process times and temperatures based solely on laboratory-grown spores.

Delayed Germination of Spores. Another important factor in establishing a process time and temperature for a nonacid product, such as asparagus, peas, or ripe olives, is the occasional delayed germination of spores of *Cl. botulinum*. Dickson, Burke, and associates, as well as Meyer and Esty and other investigators, found in some experiments that inoculated media or cans of food product were apparently sterile after heating at a certain temperature, but that after storage for several months to a year or more, growth of the spores occurred with typical spoilage and toxin formation. On this account the process times and temperatures in use in the canning industry are designed to make doubly certain that all spores of *Cl. botulinum* are killed. This phenomenon could possibly occur with other spore-bearing organisms, although the author has not found reference to such in the literature.

Use of Anaerobe No. 3679. Because of the great difficulty and uncertainty in producing in the laboratory heat-resistant spores of *Cl. botulinum* and its tendency for delayed germination, Townsend, Esty, and Baselt, as well as other investigators, have often used the National Canners Association Research Laboratory's culture No. 3679, which is a nontoxic, spore-bearing anaerobe, closely resembling *Cl. botulinum* in cultural characteristics. It is readily grown in laboratory media and possesses a somewhat greater resistance to heat than *Cl. botulinum*. Therefore death-temperature data obtained with its spores are usually more than adequate for *Cl. botulinum*.

Effect of Number of Spores. It has been shown by Esty and Meyer and others that the number of spores of the spoilage organism present initially in the canned food greatly affects the time required for complete sterilization at a given temperature. For example, in studies by the National Canners Association on flat-sour spoilage of canned corn, it was found that the numbers of spore-bearing thermophilic organisms in cans of corn were often greater in the first few cans that were packed after a shutdown for several hours or overnight and that spoilage in such cans was much more frequent than in the cans that were packed later in the day. During a shutdown the organisms had increased in numbers in various "hot spots," as in brine tanks, pumps, etc., and during the first few minutes of operation had heavily inoculated the corn passing through the line. By artificially inoculating cans of corn with various numbers of spores per can or per cubic centimeter, this observation was confirmed.

The observations of Esty and Meyer on this point with *Cl. botulinum* illustrate this principle. For example, using their strain of *Cl. botulinum* No. 97, they found the following relationships between number of spores per cubic centimeter and death time (time to destroy all spores) at 100°C. (212°F.).

Number of spores per cubic centimeter	*Death time at 212°F., min.*
72,000,000,000	230–240
1,640,000,000	120–125
32,800,000	105–110
650,000	80– 85
16,400	45– 50
328	35– 40

In commercial practice the numbers of spores of *Cl. botulinum* present in the food product will be much less than in most of the cases listed above. Nevertheless, even among relatively small numbers of spores, there may be one or more of exceptional resistance to heat, and on that account a processing time and temperature adequate to destroy such spores in non-acid foods must be considered.

F and z Values. As Townsend et al. have stated, Ball in 1928 defined the "*F* value" of a spoilage organism as the time in minutes required to destroy its spores at 250°F. in a specific medium.

If a "death-time curve" is plotted on semilog paper with temperature in degrees Fahrenheit on the horizontal axis and time in minutes to kill spores on the vertical axis, a straight line is obtained, as mentioned previously. The "*z* value" is the slope of the thermal-death-time curve expressed in degrees Fahrenheit, i.e., the temperature interval required for the line to pass through one log cycle. It measures, according to Townsend et al., the change in thermal death time with changing temperature. It is not identical for all species and strains of heat-resistant spore-bearing organisms. As the *z* value diminishes, the effect of temperature change becomes greater. For example Townsend et al. give the following example to illustrate this point.

z value	Process time required at 230°F., min.	*F* value, or process time at 250°F. to kill all spores, min.
14	138	5.11
22	44	5.47

At 230°F. the organism possessing a *z* value of 14 required 138 min. heating for destruction, and the one of 22 *z* value only 44 min.; but at 250°F. the two had approximately the same *F* value (destruction time).

Sterilizing Action during Cooling. Bigelow and associates of the National Canners Association have pointed out that considerable sterilizing action occurs during the cooling of a canned food such as corn. It is seen from their data that if the retort (process) temperature is 250°F., then about 61 per cent of the total sterilizing effect is obtained during the heating period and 39 per cent during cooling; at 240°F. 88 per cent is obtained during heating

and only 12 per cent during cooling. This would indicate that the higher the process temperature, the greater the sterilizing effect during cooling.

Other Methods of Estimating Process Time. In addition to the mathematical method of Ball, the graphic procedure of Bigelow et al. can be used. This consists in first constructing a lethal rate versus time curve from data obtained on the rate of destruction of the spores at various temperatures. The lethal rate is the reciprocal of the thermal death time at a given temperature. For example, if the time needed to destroy the spores at 240°F. is 70 min., the lethal rate is 1/70 per minute, or 0.0143. If the temperatures at the slowest heating point in the can are known during heating and cooling at various short intervals and the lethal rates at these temperatures are known, a curve of lethal rates versus time can be drawn. Bigelow et al. plotted their data for canned corn in intervals of 0.01 for lethal rate and in 10-min. intervals for time. Therefore the area of 6 squares on their diagram was $0.01 \times 10 = 0.1$, or 1/10. The area of 10 squares would be 1, or unity, and would indicate complete destruction of the spores, or a sterile product. The area bounded by the curve is measured by planimeter, and from the area so determined the sterilizing effect of the process can be judged. In order to ensure sterility the process must be long enough for this area to equal or exceed unity. For further details see *National Canners Association, Research Laboratory, Bulletin* 16-L.

A third procedure is the nomogram method devised by Olson and Stevens, for thermal processes for nonacid canned foods exhibiting straight-line semilogarithmic heating curves. Suitable diagrams are constructed from thermal-death-time temperature data and heat-penetration data, and from the diagrams the processing time at a selected temperature for a given set of conditions can be determined graphically.[1]

Thus, there are three methods of calculating or arriving at a safe processing time and temperature for nonacid canned foods from data taken on heat-penetration rate and thermal death times at various temperatures. These are (1) the graphic method of Bigelow, Bohart, Richardson, and Ball, (2) the mathematical method of Ball, and (3) the nomographic method of Olson and Stevens and others.

Process Times and Temperatures for Acid Foods. The considerations presented in the preceding several pages concerning process times and temperatures apply chiefly to nonacid foods, those of pH values above pH 4.5; the exceptions to this statement are the acid-tolerant organisms *B. thermo-acidurans* and *Cl. pasteurianum* that have caused spoilage of tomato juice, an acid product. They are discussed in the chapter on spoilage.

Most of the organisms capable of growing in and spoiling canned fruits and fruit juices of usual pH value are killed at temperatures below 212°F.,

[1] See *Food Research*, **4**(1), 1–20, 1939.

usually below 185°F. Therefore, if the slowest heating point in a can of acid fruit or bottle of fruit juice attains 185°F. or above, it will not spoil. Figs, however, are an exception since their pH value is above 4.5 and they are therefore a nonacid product. See chapters on fruit canning and on production of fruit juices for further discussion of this subject.

Limitations of Laboratory Data. In applying the theoretical process time and temperature to practical conditions, the limitations of the theoretical process must be realized, since practical operating conditions may differ considerably from the experimental. Thus the consistency of the medium may be different; the rate of rise of retort temperature to operating temperature differs; control of retort temperature during processing may not be uniform; the temperature throughout the retort may not be uniform; or the rates of cooling may differ. Another extremely important factor is that of possible difference in heat resistance of spores of bacteria grown under artificial conditions and of those occurring naturally. Still another uncertainty is the possible presence in the food under natural conditions of a species of organism of greater heat resistance than the one used in the investigation. Another important factor is the degree of contamination with heat-resistant microorganisms.

For such reasons the theoretical process temperature and time must be verified by making processing tests under practical conditions with a sufficient number of containers to give dependable results; not less than 1,000 cans should be used in such a test. Even after such a test has been made, it is necessary to apply a safety factor in order to compensate for uncontrolled variables.

Nevertheless, the theoretical process time for a given temperature is of very great value and constitutes a distinct forward step.

Effect of Hydrogen-ion Concentration on the Processing of Canned Fruits and Vegetables. It has long been recognized that acid fruits are very much more easily sterilized than most vegetables. Heating for 10 min. at 75°C. (167°F.) is sufficient to preserve plums or apricots, whereas peas and string beans require at least 4 hr. at the boiling point of water, 212°F. The most significant difference in composition between these products, as it affects sterilization, is in the acidity.

The work of Bigelow of the National Canners Association and others has shown that the total acidity of the product determined by titration is not a reliable measure of the effect of the acidity on the sterilization time and temperature, but that the hydrogen-ion concentration is a much better criterion upon which to base the relative time and temperature of sterilization of different materials.

Olson and Stevens (1942) have developed graphical methods based on nomograms for arriving at processing times at various temperatures

These depend upon Ball's equations. Their graphs are too complex to present here; the reader is referred to their paper, listed at the end of this chapter.

Bigelow and Cathcart have determined the hydrogen-ion concentration of many of the more commonly canned foods by use of the standard hydrogen-electrode equipment, as shown in Figure 30. A brief discussion of the terms used in describing hydrogen-ion concentration may make the discussion of this subject clearer.

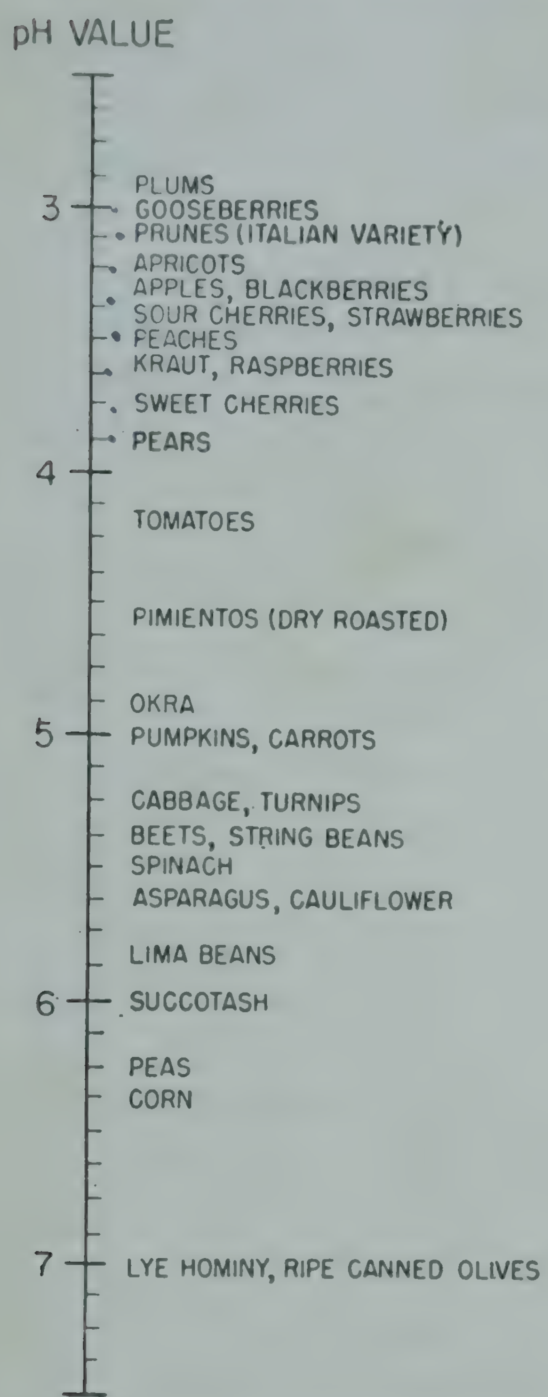


FIG. 30. pH value of various canned foods. (*After Bigelow and Cathcart.*)

Discussion of Ionization. All acids in solution in water, and water itself to a slight extent, dissociate to give hydrogen ions. The chemical formula for water is H_2O, and on dissociation it forms for each molecule of water that dissociates one hydrogen ion, H^+, and one hydroxyl ion, OH^-. The plus and minus signs indicate that the hydrogen ion carries a plus charge of electricity and the hydroxyl ion a negative charge.

The sour taste of acids is due to the presence of hydrogen ions, and the soapy feel and characteristic taste of solutions of alkalies are caused by the hydroxyl ions. Water yields equal quantities of hydrogen ions and hydroxyl ions. If there is an excess of hydrogen ions, the solution is acid in reaction; if an excess of hydroxyl ions, it is alkaline in reaction. Acids as well as alkalies vary in their degree of dissociation. Thus a 1 per cent solution of hydrochloric acid contains a very much higher concentration of hydrogen ions than an equivalent solution of acetic acid, and the hydrochloric acid for this reason is a very much stronger and more active acid than acetic acid. Titration of the two solutions would show them to contain the same total amounts of acid. The hydrogen-ion concentration, therefore, may be considered as an intensity factor for the comparison of acids.

Toxicity of Hydrogen Ion. The hydrogen ion has been termed the most toxic of all substances. If the acid of fruits were completely dissociated, fruits would be extremely poisonous, but fruits and animal and vegetable tissue of all sorts contain buffer substances that prevent the formation of

excessive amounts of hydrogen ions. Nevertheless, the concentration of hydrogen ions in most fruits is sufficient to affect the death temperature of microorganisms very materially.

Methods of Expressing Hydrogen-ion Concentration. Hydrogen-ion concentration is expressed in several different ways. Expressed as grams per liter, water contains 0.0000001 gram of hydrogen ions per liter, and gooseberries contain 0.001 gram per liter. Expressed in powers of 10, these figures become 1×10^{-7} and 1×10^{-3}, respectively. The reciprocals of these quantities are 10,000,000 and 1,000 respectively. The logarithm of the reciprocal of the weight in grams per liter of hydrogen ions is probably the most common means of expressing hydrogen-ion concentration. For water it is 7, and for gooseberries 3. This logarithm is called the "pH value." The more acid the substance, the lower the pH value becomes.

Table 13 gives a comparison of the various methods of expressing

TABLE 13. HYDROGEN-ION CONCENTRATION OF THE JUICES OF TYPICAL CANNED FOODS

Product	Weight of hydrogen ions, grams per liter, expressed		Reciprocal of weight, grams per liter	Logarithm of reciprocal, pH value
	As decimal	*In powers of 10*		
Gooseberries	0.001	1×10^{-3}	1,000	3.0
Tomatoes	0.000063	6.3×10^{-5}	15,850	4.2
Pumpkin	0.00001	1×10^{-5}	100,000	5.0
Corn	0.0000005	5×10^{-7}	1,955,000	6.3
Lye hominy, ripe olives, water	0.0000001	1×10^{-7}	10,000,000	7.0

SOURCE: After Bigelow and Cathcart.

hydrogen-ion concentration for several canned foods that represent a wide range of pH values. Within a given variety of fruit there may be a considerable range in pH value due to differences in ripeness and other conditions.

It will be seen from this table that gooseberries have 10,000 times the hydrogen-ion concentration of lye hominy. This is the reason why the former are very easily sterilized and the latter very difficult to sterilize.

Most fruits have a high hydrogen-ion concentration, and most vegetables a lower concentration than tomatoes. Tomatoes of normal pH value are easily sterilized at 100°C. (212°F.). Pimientoes also can be sterilized at the same temperature (212°F.) and have a hydrogen-ion concentration slightly higher than that of tomatoes. When, however, a pH value of 5 is approached or exceeded, the product enters the class of materials that normally requires sterilization under pressure. The accompanying figure after Bigelow and

Cathcart, on page 116, illustrates clearly the relative positions of various canned foods in the hydrogen-ion-concentration scale. In studying the chart it must be borne in mind that *high pH value* means *low hydrogen-ion* concentration.

Experiments by E. C. Dickson of Stanford University have proved that the death temperature of spores of *B. botulinus* (*Cl. botulinum*) is greatly reduced by the acidification of the medium with organic acids, e.g., citric or acetic acid. Experiments performed by the author in 1915 proved that peas, string beans, corn, and fish inoculated with spores of *B. botulinus* were sterilized perfectly in 1 hr. at 100°C. by heating in dilute brine acidified with lemon juice to approximately 0.2 per cent acidity expressed as citric. The same products not acidified developed a vigorous growth of the organism, even after 3 hr. boiling in sealed containers, and were very toxic to guinea pigs, producing typical symptoms of botulism and death when administered in small doses. The experiments were repeated by a graduate student (see Cruess, Fong, and Liu) in the Fruit Products Laboratory at the University of California with similar results. Weiss at the Harvard Medical School and others have since confirmed these results. In California the State Board of Health on the basis of research of K. F. Meyer, J. R. Esty, E. C. Dickson, and others has established pH 4.5 as the dividing line between acid and nonacid foods. Thus the Board requires that artichokes canned in acidified brine shall have after canning a pH value of less than 4.5. The author believes this method has great commercial possibilities for other vegetables for salad use. Sognefest, Hays, Wheaton, and Benjamin (1948) confirmed the conclusion of earlier investigators that the death time at a given temperature decreases with decrease in pH value.

Household Application of Acidified Brines in Canning. The "lemon-juice" method was at one time in general use in California for the home canning of vegetables (Cruess, 1915), and was revived during the Second World War because of lack of pressure cookers for home use. For most vegetables canned by this method the brine is acidified with 16 fl. oz. of lemon juice per gallon of dilute brine; i.e., this amount of lemon juice is placed in a gallon measure and brine added to make 1 gal. Vegetables canned in this manner possess a slight acid flavor, but this is eliminated if a pinch of baking soda is added when, after opening the can, the vegetables are placed in a kettle for cooking. The canned vegetables possess the full fresh vegetable flavor and are superior in flavor to the same materials sterilized under pressure in the usual manner. However, it was finally deemed advisable to discourage the use of this method, since some housewives failed to apply it properly, with resulting danger of botulism. It has been replaced by sterilization of the nonacidified products under steam pressure.

The dilute brine is made by dissolving about 2 oz. of salt per gallon of water and adding lemon juice, as previously mentioned. Vegetables to be used for salad are especially satisfactory when preserved in cans or glass jars with acidified liquid. A good salad mixture is string beans, carrots, asparagus, beets, and peas.

Buffering Action of Vegetables. Buffering action may be explained as the tendency of a solution or substance to resist change in pH value on the addition of acid or base. For example, a solution containing sodium acetate and acetic acid is a buffer solution containing a weak, only slightly dissociated acid and a nearly completely dissociated salt of the weak acid. When dilute, highly dissociated acid of low pH value is added, such as dilute HCl, it reacts with the sodium acetate to form acetic acid, most of which goes into the undissociated form, and an equivalent amount of sodium chloride is formed. If dilute sodium hydroxide solution is added, the dissociated acetic acid reacts with it to form water and sodium acetate. Some of the previously undissociated acetic acid dissociates, thus replacing most of the hydrogen ions neutralized by the hydroxide.

Thus this buffer solution tends to maintain its original pH value when either acid or base is added.

Plant tissue, including that of fruits and vegetables, contains weak organic acids such as citric, malic, and tartaric acids and their salts, both the acids and the salts being in solution in the sap or juice of the plant tissue. Therefore, when prepared vegetables are placed in acidified water or acidified dilute brine and heated, they exert a buffering action toward maintenance of their original pH value.

The extent of this buffering action is very appreciable. In experiments by Cruess, Fong, and Liu (1925) it was observed that the pH value of acidified dilute brines increased markedly during exhausting or sterilization. The extent of these changes is illustrated by the following data.

Asparagus was canned in dilute brines acidified with hydrochloric acid in one case, citric acid in another, and acetic acid in another. The original pH value of the three solutions was 2.6; after sterilization it had become pH 5.4 for the dilute hydrochloric acid solution, pH 5.1 for the citric acid solution, and pH 4.6 for the acetic solution. At an initial pH of 2.0 with citric acid, the final pH was 3.2.

Similar changes were observed at other pH values. With asparagus and string beans, the buffering action was less than with peas. To give a final pH value of less than 4.5, an original acid solution containing not less than 1.0 gram of citric acid per 100 cc. was required for peas, 0.4 per cent for asparagus, and 0.4 per cent (grams per 100 cc.) for string beans. These values will vary with the ratio of acidified liquid to vegetable, of course.

The stronger the kind of acid used, the less is required to give a solution

of given initial pH value. For example, much less hydrochloric acid is needed than of citric to acidify a liter of solution to pH 2.5, because the hydrochloric acid is practically completely dissociated and the citric only slightly so. For this reason, when a buffer substance or alkali is added, the hydrogen ions of the hydrochloric acid "used up" by the buffer or alkali are not replaced, as there is no reserve of undissociated acid. On the other hand, the citric acid is only partly dissociated, and as its hydrogen ions are neutralized more of the acid dissociates, thus resisting increase in pH value. This reaction will explain the differences in pH value changes observed by Cruess, Fong, and Liu during the canning of various vegetables in dilute brine acidified with hydrochloric, citric, and acetic acids.

G. L. Marsh, of the author's staff, in 1938, extended the studies on the canning of nonacid vegetables in acidified dilute brines and determined their buffering power more closely. He points out that the volume of acidified liquid per 100 grams of prepared vegetable in the can or jar affects the pH change very materially. He found that vegetable juice exerted about as much buffering action in the cold state as when heated. His data indicated that salts of weak acids rather than proteins are the principal natural buffers of nonacid vegetables.

Possible Commercial Use of Acid in Canning. Nonacid foods are seldom acidified in present commercial canning practice. Artichokes are acidified as described in Chapter 10, Canning of Vegetables. However, it is likely that some other vegetables, such as string beans and asparagus, would prove acceptable to consumers if acidified in canning. Mixed vegetables for use in salad are even more suitable for this purpose if acidified than if canned without added acid. This product has been canned quite successfully in experiments in the author's laboratory in a 1½ per cent salt solution to which has been added 1 per cent of citric acid. The process used was 1 hr. at 212°F.

Peas respond well to the method of canning except for lightening of the color, although the color is about equal to that of peas canned in the usual manner. The flavor and texture of the acidified peas processed at 212°F. are much superior to those of nonacidified peas processed at 236 to 240°F. in the customary commercial manner.

Spinach should be blanched in acidified water in addition to being canned in acidified brine, since it is difficult with the small volume of liquid added to spinach to secure uniform acidification of all the spinach in the can.

Celery, pimientoes, asparagus, string beans, peas, carrots, beets, broccoli, sprouts, cauliflower, fresh cucumbers, sliced lettuce as a vegetable (not as a salad), and several other vegetables respond well when acidified in canning. Corn, sweet potatoes, and white potatoes are not very satisfactory when canned in this manner. The sirup used in the canning of figs is now acidified.

PROCESSING METHODS AND EQUIPMENT

In the first section of this chapter the theory of processing was discussed. the present section the application of these principles to practical nning operations will be described.

Comparison of Fruits and Vegetables. The nature of the fruit or vegetable be canned will affect the type of processing equipment to be selected and ll determine the temperature and time of processing. All fruits, with the ception of olives, are sterilized at 212°F. (100°C.). The acidity of fruits d acid vegetables, such as tomatoes and rhubarb, makes it possible to ocess them with safety at 212°F. Other vegetables, however, because of ir low acidity, their hard texture, and during growth, their proximity to l where they may be contaminated with spore-bearing organisms, quire much more severe processing than fruits. Temperatures that would oil the color, flavor, texture, and appearance of fruits in many cases improve the flavor and texture of vegetables. Vegetables are therefore usually ocessed at temperatures above 212°F.

Heat Units Required. Since the specific heat of most fruits and vegetables practically that of water, the error is small if we assume that the same nount of heat will be required to heat a can of corn, peaches, etc., as is quired to heat a similar can of water.

The British thermal unit (B.t.u.) is generally employed in expressing heat antities commercially. It is the amount of heat required to raise the temrature of one pound of water 1°F.

For the sterilization and other heat treatments of 70,000 cans of No. 2½ ze of fruit or vegetable the following calculations might be considered to dicate the approximate amount of heat required.

Suppose the average initial temperature is 80°F. and the product is to be ocessed at 212°F. The temperature rise is 132°F. As each can of product eighs about 2 lb., the total weight to be heated is about 140,000 lb. The .t.u. needed to bring the product to 212°F. will be 140,000 × 132, or 3,480,000 B.t.u. if no heat is lost by radiation, etc. At least an additional 3 per cent should be allowed for scalding or preheating, thus making the tal minimum per can at least 264 B.t.u. To this must be added the heat sed for other purposes, such as exhausting, steam-flow seaming, mainining the canned product at 212°F. for the required time, etc.

Relation of Steam Pressure to Temperature. In a closed retort heated ith steam, the temperature will vary according to the steam pressure. able 14 shows the relation between steam pressure and temperature.

Effect of Altitude on Sterilization. For each increase of 500 ft. in altitude, he boiling point of water decreases approximately 1°F. The usual recom-

TABLE 14. RELATION OF STEAM PRESSURE TO TEMPERATURE OF CANNING RETO

Pressure, lb. per sq. in.	*Temperature, °F.*
1	215.2
2	218.3
3	221.3
4	224.2
5	226.9
6	229.5
7	231.9
8	233.3
9	236.6
10	238.8
11	241.0
12	243.0
13	245.3
14	247.3
15	249.1

mendation for the sterilization of fruits or vegetables at the boiling point at high altitude is to increase the time of sterilization 2 min. for each degree Fahrenheit below 212°. Altitude also affects the temperature of a steam retort operating at pressures in excess of atmospheric pressure by amounts given in engineering handbooks. The effect of altitude upon the boiling point of water is shown in Table 15.

TABLE 15. THE EFFECT OF ALTITUDE UPON THE BOILING POINT OF WATER

Altitude, ft.	Boiling point of water	
	°F.	*°C. (approx.)*
0	212	100
1,025	210	99
2,063	208	98
3,115	206	97
4,169	204	96
5,225	202	94
6,304	200	93
7,381	197	92
8,481	196	91
9,031	195	90

Increase of Boiling Point by Addition of Salts. The boiling point of water may be increased by the addition of sodium chloride, calcium chloride, or other salts. This fact was made use of in the sterilization of meats ar vegetables during the early years of the canning industry. It is possible obtain a temperature of more than 240°F. by the addition of calciu chloride.

Sterilization in concentrated calcium chloride solution, however, has two objections: (1) the cans are subjected to excessive internal pressure, and bursting of many may occur; and (2) the sterilized cans must be thoroughly washed to remove the adhering solution in order that corrosion of the tin plate may be prevented. The calcium chloride bath is no longer used commercially in the United States.

Discontinuous Open Cookers. Until about 1912 the sterilization of canned fruit and some vegetables was accomplished in open wooden tanks filled with boiling water into which the cans were lowered in crates by means of a crane. This method is still in use in small canneries and in large canneries to a limited extent in the sterilization of small miscellaneous lots of fruit. The water is maintained at the boiling point by open steam jets.

Continuous Nonagitating Open Cooker. The first improvement on the discontinuous open cooker for canning of fruits was the continuous nonagitating Dixon cooker, a long wooden tank containing boiling water through which the cans placed in metal baskets were carried by an overhead conveyer. It was in common use in California fruit canneries until about 1912. The objections to this cooker were (1) that it was very inefficient in its use of steam and wasted large amounts of heat through the evaporation of water from the sterilizer; (2) that the time of sterilization was difficult to regulate and adjust; (3) that the sterilizer occupied too large a floor space; and (4) that it was complicated and costly in operation. The Dixon cooker has been wholly replaced by the agitating continuous open cooker.

By the term "open" the commercial canner understands a cooker that operates at atmospheric pressure. The term is somewhat misleading for the reason that the usual cooker is almost completely enclosed. It operates, however, at approximately 212°F. (100°C.).

Continuous Agitating Cookers. The appearance of a typical continuous agitating cooker may be seen in Figure 31. The can enters a small porthole at one end of the sterilizer and travels along a spiral inside the sterilizer. The method of conveying the cans is shown in Figure 31. During its course through the processor it is rolled, and thereby the contents are thoroughly agitated, with consequent increase in heating rate of can contents.

At present most of the processors in use for fruits and tomatoes consist of a long metal tank of heavy boiler plate, inside of which is a spiral extending throughout the length of the processor and a cylindrical reel which revolves inside the spiral, thus carrying the cans forward through the processor (Figure 31). The modern processors of this type are fitted with a number of inlet or outlet doors near the top of the processor in order that the process time may be varied at will. It may be filled about three-fourths full of water for processing the cans under water; or it may be used without water for processing the cans in live steam only or operated on the basis of

half steam and half water. There are advocates of each method of operation. However, the water method of operation has one very important advantage: it permits operation at any desired temperature, for example, at 160°F. for the pasteurization of canned fruit juices. In the processing also of canned fruits in the water method of operation, it is now customary in many canneries to equip the processor with a temperature controller and to process at a temperature 1 to 2°F. below the boiling point of water, instead of at the boiling point. Operation at the boiling point results

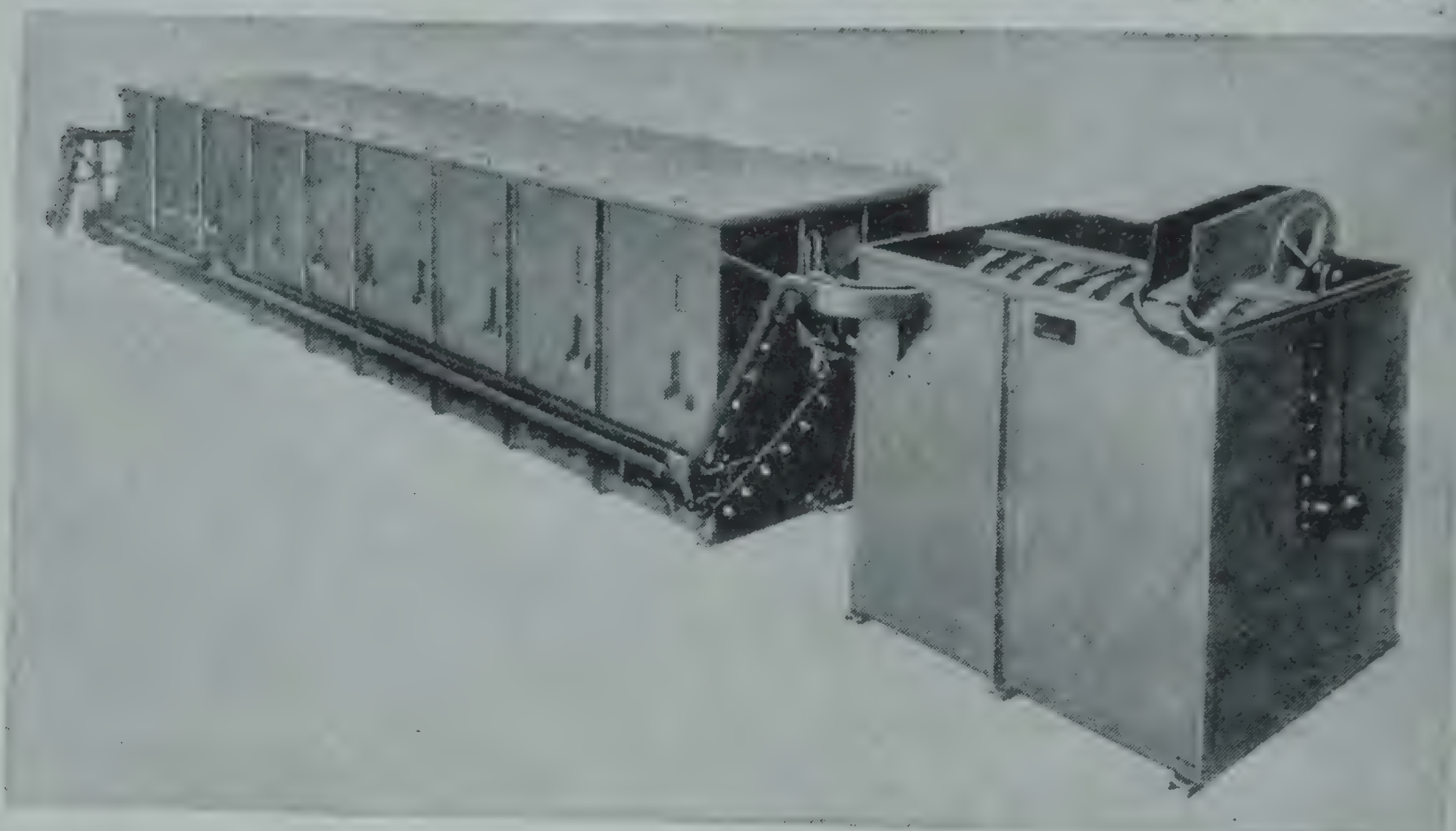


FIG. 31. Continuous agitating processor for canned fruits and tomatoes. (*Food Machinery Corp.*)

inevitably in heavy loss of heat. It requires about 1000 B.t.u. to evaporate 1 lb. of water and only about 140 B.t.u. to heat 1 lb. of water to 210 to 211°F. Operation slightly below the boiling point also permits use of a temperature controller that will close or throttle down the steam line during the frequent intervals when cans are not entering the processor; whereas if operation is at the boiling point, use of an automatic temperature regulator is not possible and manual operation of the steam valve is necessary. Canners have found that the water method with automatically controlled temperature 1 to 2°F. below the boiling point results in very important saving of fuel. It also results in far less escape of steam into the cookroom, and thus in better working conditions.

Formerly most of the processors were rectangular in cross section; then for a time many were cylindrical in form and of circular cross section. The present trend is toward a processor shell the lower half of which in cross section is a half circle and the upper half is a rectangle. This design permits ready access by lifting off the flat lid, in contrast with the cylindrical processor, which is very difficult of access. Ready access is important,

as it is usually necessary to open the processor several times during the season, to remove cans that have become crushed between the reel and spiral and thus have brought operation to a standstill.

The capacity of the processor ("cooker") in cans per minute varies, naturally, with its length and diameter and with the length of the process. The output in cans per minute is found by dividing the number of cans held by the processor with reel completely filled by the length of the process in minutes. Thus a large processor for No. 2½ cans holds 3,105 cans. With a 20-min. process it will "turn out" 155 cans per minute. In actual practice, however, the maximum holding capacity of the processor is seldom used, as the length of process is controlled by use of portholes for entry or emergence of the cans at various points along the side of the processor, rather than by using the entire length of the processor and governing the length of process by varying the speed of rotation of the reel. Thus a can given a 10-min. cook would traverse only half the distance traveled in the processor by one given 20 min. processing. Normally, the siruping machine, can-closing machine, exhaust box if used, and processor are synchronized in operation, in order that the can may move through each at a uniform rate.

Discontinuous Nonagitating Retorts. To a canner a "retort" signifies an autoclave or closed processor in which the cans are heated in steam under pressure. In an open processor using water as the heating medium, the maximum temperature attainable is 212°F.; whereas in a retort, temperatures of 240 to 260°F. or higher are readily attainable.

The simplest form of retort is an upright or horizontal heavy steel cylinder in which the cans are placed in crates and which is operated with steam under pressure. In California the horizontal retort is the more popular, but in Eastern canneries the small upright retort, which is sunk below the floor level, is in common use. The advantage claimed for the horizontal retort is that cans may be placed in crates or small steel cars, which can be quickly and easily placed on a steel track in the retort. In some cases both ends of the retort are fitted with heavy swinging doors, so that after sterilization the cars of sterilized cans may be removed from one end of the retort while loaded cars may be entered at the opposite end. The appearance of a horizontal retort is shown in Figure 58. The usual size is approximately 60 in. by 10 to 20 ft.

The upright retorts are used in a battery above which is a traveling crane, usually operated by air pressure. Cans are filled into circular crates that are lowered into the retorts. It is claimed for this style of retort that, because only a small quantity of material is required to fill it, the exhausted or the sealed cans are not allowed to stand very long without sterilization and hence do not have an opportunity to cool appreciably before sterilization.

Retort Operation. Three important methods of heating retorts are in use, viz., steam, steam plus air, and water plus air. The first is used for canned products to the practical exclusion of the other two methods. The steam-plus-air and water-plus-air methods have been used for glass containers; because the jar lids would be forced off at processing temperature, the extra pressure is required to hold the lids in place on glass containers. In California use of the steam-plus-air method is prohibited by the State Board of Health, owing to the difficulty of securing uniform and rapid heating of the contents of the retort by its use. While this method may be permitted in some other states, the author strongly advises against it for the reasons given, and he recommends instead that water plus air be used, as later described.

It is essential in the pure-steam method of operation to vent the retort generously through vents in the top of the retort during the coming-up period in order to remove all entrapped air; otherwise heating will not be uniform. After the retort has attained operating temperature the thermometers and pressure gauges should "agree"; e.g., if the operating temperature is 240°F., the pressure gauge should show slightly more than 10 lb. pressure. A pressure much higher than 10 lb. at 240°F. indicates the presence of entrapped air. Somers states that it is possible to have uneven heating, even after the pressure gauge and thermometer agree, because of entrapped air. See also discussion of venting below.

After retort temperature is attained, the vents may be closed and only the small pet cocks ("bleeders") left open to allow as much steam to escape as is necessary to remove noncondensable gases entering with the steam and to promote circulation. After the cans have attained retort temperature, they tend to maintain a constant temperature throughout the retort, so that the presence of air is then less objectionable than during the coming-up period. An experimental retort is shown in Figure 26.

The most potent cause of irregularity in temperature in a vertical retort during the coming-up period is condensation of the steam on the cans near the point of entry of the steam. In other words, the steam as it enters early in the heating period gives up its heat to the relatively cold cans and is thus condensed to liquid water. This process leaves that much less steam to rise and heat the cans above.

It is extremely important that the pocket surrounding the bulb of the thermometer be thoroughly vented at all times in order that live steam will flow around the bulb, which can then, and only then, respond to the true retort temperature.

The location of the bulb of the temperature-control device is of importance. When placed in the bottom of the retort near the steam inlets, it responds to the temperature of the surroundings there, and as these reach retort temperature sooner than the region near the top of the retort, the

ontroller may close the steam-supply valve before the cans in the upper part of the retort have attained retort temperature. In this manner their attainment of retort temperature may be seriously delayed, and consequently they may receive insufficient processing. It is customary to locate the bulb in a pocket in the wall of the vertical retort toward the top (Figure 28).

Vertical Retorts and Glass Containers.[1] In the processing of glass containers the vertical retort is filled with water, the retort being equipped with an overflow valve or otherwise protected against bursting because of excessive pressure attained by expansion of the water and condensation of steam. For a vertical retort the overflow line should be 2 in. in diameter and equipped with a controller. Steam is admitted by a 2-in. line for vertical retorts to heat the water, and air is admitted to mix the water and maintain the additional pressure required to hold the lids of the jars in place. The steam and air should be mixed outside the retort so that the air may be heated before entry and the "rumbling" minimized. The top of the retort should be well vented. The water level should be well above the topmost jars; otherwise, as Parcell's data showed, the jars resting only in air plus steam will drop below retort temperature. A sight gauge (glass tube) on the side of the retort is very useful for showing the water level. Instead of venting the thermometer pocket, Parcell recommends forced circulation of water through the pocket, attained by connecting the pocket to the steam line by a small pipe. The water is circulated by pump in horizontal retorts used for glass. Air is used also to hold lids in place.

Parcell found that the water-plus-air method gave much more uniform heating of containers at different levels in the retort during the coming-up period than was possible with steam alone or with steam plus air. It required more heat units, naturally, because of heat required to bring the water to retort temperature. The air not only provides the extra pressure required but also stirs the water and thus prevents local overheating or underheating. It is usual practice to admit the air and steam through a perforated pipe cross in the bottom of the retort; but Parcell found that heating and mixing are more satisfactory by a method patented by him under U.S. Public Service Patent 1,708,105, April, 1929. It consists in mixing the air and steam outside the retort and admitting the mixture through three tangentially placed muffled jets, which give a vigorous rotary motion to the water. Air rising from the jets gives additional agitation. This hookup gives very rapid and uniform heating with very little noise and vibration ("rumbling"). In processing at 240 to 250°F. the total pressure in the retort should be 27 to 28 lb. per sq. in.

[1] Thanks are due the packaging and planning department research division of the Owens-Illinois Glass Company for some of the information presented in this and the following sections.

The Owens-Illinois Glass Company research staff recommends that a pressure-control valve be placed in the overflow line, that temperature in the retort be controlled independently of the pressure, that glass jars be processed in water, and that compressed air be provided to the retort. Detailed directions can be obtained from the company.

When the processing period is completed, rapid cooling of the contents is necessary to arrest cooking. Cold water admitted directly against glass containers would break them; releasing the pressure would allow the lids to be forced from the jars by the internal pressure of their contents. Consequently, in cooling glass jars it is advisable to temper the ingoing water by heating it with steam to a safe temperature and gradually to drop its temperature as cooling progresses. At the same time air is admitted to maintain sufficient pressure to prevent loss of lids. The air rising through the water mixes it and prevents "blanketing." The Owens-Illinois Glass Company recommends admitting cooling water at the top of the retort beneath the level of the water.

In cooling cans it is not necessary to temper the water; cold water may be admitted directly. However, it is necessary for large cylindrical cans and advisable for medium-size and square asparagus cans, to provide air pressure sufficient to prevent buckling.

Horizontal Retorts and Glass Containers. In the retorting of glass containers in horizontal retorts, recirculation of water within the retort is essential. Recirculation is accomplished by means of a motor-driven pump that takes the water from the bottom of the retort by suction and returns it to the top of the retort. Openings in the suction line should be placed 6 to 9 ft. apart; the state of California requires that they be not more than 8 ft. apart. The pump should be capable of recirculating all the water in the retort in 7 min. or less. The pump should be fitted with a warning device, such as flashing on of a red light, if the pump for any reason is not functioning properly. The line should be equipped with a ⅛-in. pet cock as a bleeder to remove any entrapped air and thus avoid an air lock in the line.

The pump discharges the water into the top of the retort through a perforated pipe that is attached along the inside top of the retort. The temperature-recording thermometer that controls the steam-inlet valve is connected into the discharge side of the water-recirculating line. It is a good plan to insulate the water lines to minimize heat losses.

It is desirable to have a hot-water storage tank for use in filling the retort at the beginning of the run. The hot water from the first stage of cooling can be returned to the tank for the next run.

Water for cooling is injected into the recirculation line on the suction side of the pump. A liquid-level gauge should be provided to indicate the water level in the retort. Temperature and air pressure should be controlled

separately. For further details the reader is referred to the research department of the Owens-Illinois Glass Company, San Francisco, or to the same department and company, Toledo, Ohio.

Advantages of Steam. As Somers points out, steam is a good medium for processing canned foods in a retort, first because of its high latent heat. When steam condenses on the cans, it liberates nearly 1000 B.t.u. per lb. (i.e., per pound of steam or its water equivalent by weight) and thus causes very rapid heating of the cans and contents.

Steam also furnishes pressure against the outside of the cans and helps to counteract the pressure built up in the cans during heating. It is also easily generated and easily controlled. Pure steam is used as the heating medium for cans in retorts, and, as stated elsewhere, water is used for heating glass containers in retorts; in this case air under pressure is admitted to provide sufficient pressure to keep the lids in place during the processing. The water is heated by steam.

Discussion of Venting. Since the presence of appreciable amounts of air in a retort using steam (not water) as the heating medium greatly lessens the heating value of the medium, it is essential that the air be removed from the retort as nearly completely as possible. Somers believes that the irregular heating of certain cans in the retort observed by him after the thermometer and pressure gauge were in agreement was due to residual air in the retort. Perhaps this is the case, though the following explanation is also possible: For several minutes during the early stages of heating, cans in the center of the load may not receive much steam because most of it is condensed on the cans nearer the steam entry ports, and until these cans are well heated there may be little steam to heat those at greater distance from the steam inlet. This situation was actually observed repeatedly by Parcell in experiments with vertical retorts.

Whatever may be the cause of these irregularities in rates of heating of cans at different locations in the retort, venting should be very generous and thorough, if for no other reason than that it provides a superabundance of steam in the initial stages of heating, so that it heats all the cans more rapidly and thus tends to iron out inequalities. Also, of course, it removes the air that much more rapidly. In other words, the more generous the steam supply and the larger the vents, the more promptly is the air removed. Somers states that a horizontal retort when fully loaded has 70 to 80 per cent of its space occupied by air, and a fully loaded vertical retort, 60 per cent of air. This fact is often not appreciated. During the initial period when the retort is heavily vented, much steam is wasted; much less steam is needed per minute during the subsequent holding period when comparatively little steam is lost by venting.

Somers (1944) gives 10 typical venting diagrams for horizontal and vertical retorts. For example, he recommends a 1-in. vent open to the

atmosphere for every 5 ft. of length of horizontal retort of standard height, with vents placed not more than 2½ ft. from the ends of the retort and equipped with gate valves. He also recommends that vents be wide open for at least 5 min. to at least 225°F., or for at least 7 min. to at least 230°F. The reader is referred to his paper for other examples.

He emphasizes the importance of construction of can trays and crates in relation to venting. Trays and crates made of strap iron permit free flow of steam and thus rapid sweeping out of air by the steam. If, however, they are made of sheet metal with small holes to provide steam passages, the cans may cover many of the holes or they may be too small; in either case, steam flow and air removal are impeded. For sheet-metal crates Somers recommends holes at least 1 in. in diameter and 1¾ in. on centers.

If cans are stacked vertically in deep crates, long columns may result and thus impede steam flow; but single vertical layers in trays are satisfactory. In deep crates and gondolas, Somers favors horizontal or "helter-skelter" ("jumble") stacking, either of which permits good steam flow. He condemns the use of burlap sacks, boards, sheet metal, or similar materials used as dividers or markers in the retort load, as they seriously impede steam flow and air removal.

He emphasizes the need for an ample steam supply, meaning, first of all, ample boiler horsepower, and secondly, delivery pipes and spreaders of ample capacity. Thus for a horizontal retort up to 12 ft. in length, the steam-delivery pipe should be at least 1¼ in. in diameter, and 2 in. is preferable for longer retorts.

The spreader pipe in the bottom of the retort should have holes in its top so that the steam is directed upward into the load and not against the walls of the retort, thus driving the air out of the center of the load. He suggests eight holes ¼ in. in diameter per foot of spreader pipe, the spreader pipe to be not less than 1½ in. in diameter for spreader sections up to 9 ft. in length.

Perforated baffle plates in the bottom of the retort are objectionable because they tend to direct the steam flow around the load rather than vertically through it.

See references at the end of this chapter for further details on venting and retort operation.

Records of Processing. It is of great importance to the canner to mark the cans of each retort load with an identifying code mark, so that the cans of the affected lot can be segregated if spoilage or other difficulty develops later. In California such coding is compulsory and under State Board of Health supervision, and in addition the canner must equip each retort with a recording thermometer. The temperature curve for each load is recorded on the thermometer chart and is given an identifying

mber in order that it may be correlated with the lot code on the cans. ne chart is filed with the State Board of Health for future reference.

Temperature Control and Recording. In up-to-date, well-equipped nneries the temperature of retorts, open cookers, and exhaust boxes is ually controlled automatically. The automatic controller not only gives

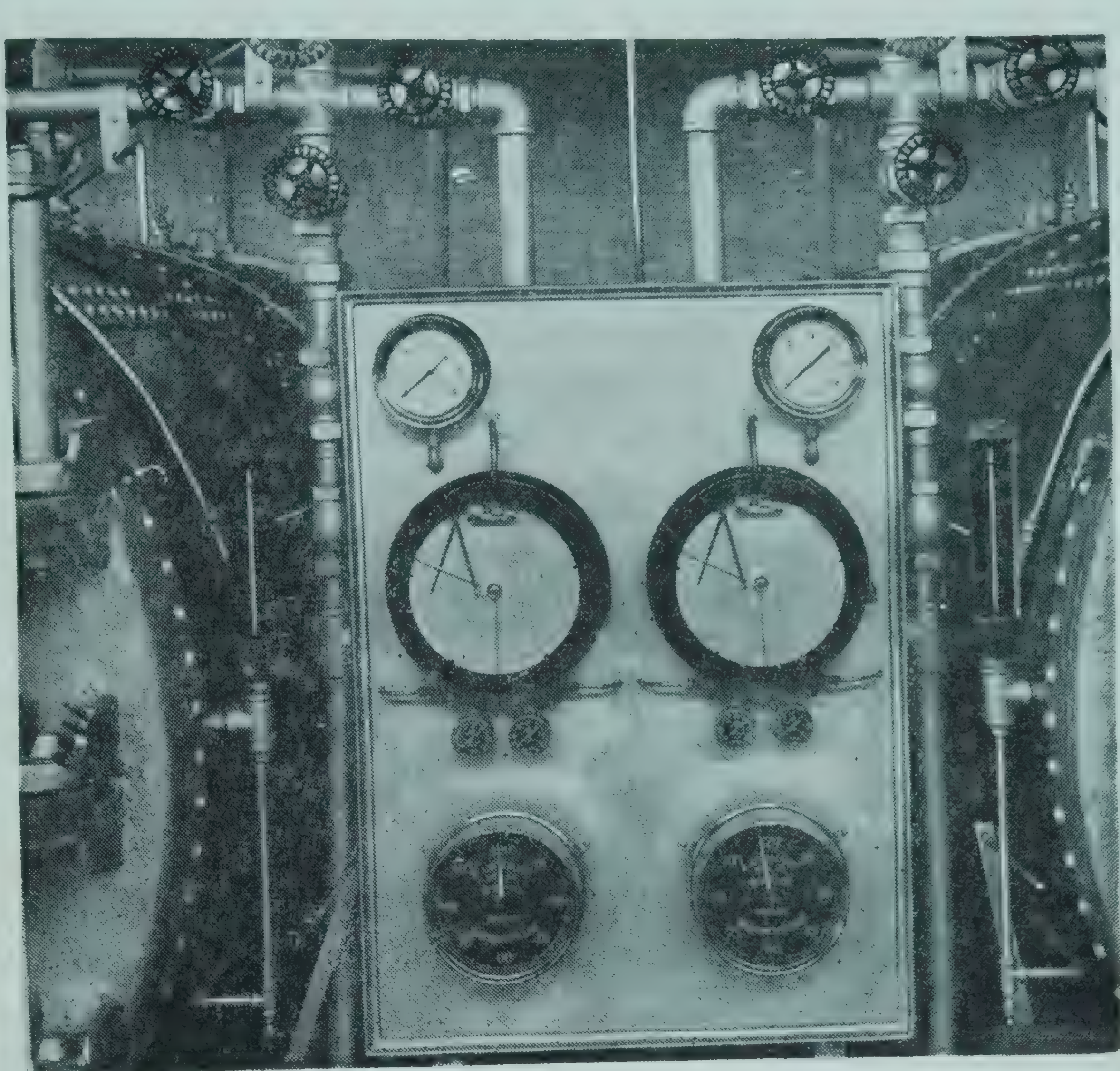


FIG. 32. Temperature-control and -regulating instruments for retorts in a cannery. (*Tagliabue Manufacturing Co., New York.*)

much closer control of temperature but also results in an important conservation of steam and reduced labor cost.

Controllers are of two general types, viz., self-actuated and indirect-controlled. The former does not give very close control and therefore is not suitable for use on retorts, although it is satisfactory for exhaust boxes and certain other equipment where closely controlled temperature is not essential. One form of direct-acting regulator consists of a metallic rod fixed at one end and attached to a lever arm at the other end. As the rod expands with rise in temperature, it operates a valve to close the steam line, and as the temperature drops, contraction opens the valve.

Most controllers used in canneries are of the vapor-tension, air-controlled type. The instrument usually consists of a temperature-measuring element consisting of a metallic bulb half filled with a low-boiling liquid, such as

ethyl ether, the bulb being connected by a small metallic tube to a helical metal coil in the instrument case. The free end of the coil is attached to a pen arm fitted with an ink-filled stylus resting on a circular chart. The ether or other liquid gives off vapor in proportion to the temperature of the retort, causing a corresponding rise in pressure in the vapor in the bulb, connecting tube, and helical coil, which in turn expands or contracts ("coils" or "uncoils") and moves the pen arm and stylus across the chart correspondingly. The chart, rotated slowly by a clock mechanism, gives a complete record of heating, holding, and cooling the retort load. Formerly the bulb, the connecting tube, and the helical tube were filled completely with fluid (usually mercury); but such an instrument is sluggish in action and is seriously affected by the temperature outside the retort and on this account is often inaccurate. The vapor-tension instrument is not subject to such error, since pressure in the line is that at the liquid-vapor interface in the bulb.

The pressure in the bulb of the temperature controller also actuates the temperature-controlling mechanism, usually by means of an air-controlled steam valve as shown in Figure 28. Briefly, the mode of operation is about as follows in one typical instrument: Compressed air is admitted to the instrument from a compressed-air reservoir through a reducing valve set at about 20 lb. pressure per sq.in. The small tube which carries compressed air is closed when operating temperature is attained; when the temperature drops, the vapor pressure in the control bulb drops and the helical coil in the instrument contracts, opening a flapper valve over an orifice in the air line and thus allowing the air pressure to operate a steam valve in the main steam line to the retort. As temperature is again attained, the vapor pressure increases in the bulb and expands the helical coil, which in turn closes the flapper valve of the air-control system, and hence closes the air line to the steam-control valve, which is then closed by a powerful spring. Details of the mechanism vary with different makes of air-controlled instruments, but all make use of compressed air either to open the steam valve (direct acting) or to close that valve (reverse acting). The direct-acting valve is the more desirable because, if for any reason the control system should fail to operate, all that can happen is that the steam valve is closed by the spring and processing ceases; whereas with a reverse-operating instrument a breakdown would leave the steam valve open, with the result that the pressure might rise in the retort to the bursting point.

Electrically operated temperature instruments are now coming into use for control of temperature in processors. A control bulb of the vapor-tension type previously discussed is inserted in the retort or other processor. Vapor pressure operates a helical coil, which in turn makes and breaks contact with an electrical circuit containing a relay and a solenoid-operated

r motor-operated valve in the steam line. The controller is sensitive, ccurate, and, except when power service is interrupted, dependable. It an be made to operate a signal light or other signaling device. It is possible o equip the retort with a timing device that will turn off the steam when he process is completed.

For additional details of temperature measurement and control see Foote, Fairchild, and Harrison; Parcell; and booklets of various firms such as the Foxboro Instrument Company, Tagliabue Company, Taylor Instrument Company, Brown Instrument Company, the Bristol Company, and Leeds and Northrop Company.

Process Times and Temperatures. The National Canners Association has issued a bulletin (26-L) of very great importance to the canners of nonacid vegetables. It is revised occasionally. It gives processing temperatures and times for different sizes of cans for all the important nonacid canning vegetables. Because of its length, it is not practicable to reproduce the table in this book. Many of the recommended processes are given, however, in Chapter 10, Canning of Vegetables.

The bulletin makes the following additional recommendations. Cans, except those sealed under mechanical vacuum, should be sealed at not less than 130°F. in order to prevent undue strains on the can and to maintain a concave appearance after processing. Each retort should have (1) an automatic temperature controller, (2) an indicating mercury thermometer, (3) a recording thermometer, (4) a pressure gauge (preferably of compound type), (5) a vent of at least ¾ in. inside diameter, to be used during the coming-up period, (6) a ⅛-in. bleeder in each thermometer pocket, (7) at least one ⅛-in. bleeder in the top of the retort, (8) a steam bypass around the controller to permit rapid rise in temperature, and (9) a perforated steam line entering the retort at the bottom beneath a perforated steel plate. The recording thermometer should have a range of 170 to 270°F., and the scale divisions should not exceed 2°F. The pressure gauge should have a range of 0 to 30 lb. and should be graduated in 1-lb. divisions. At least two-thirds of the length of the bulb of the controller-recorder should extend into the principal chamber of the retort.

The blowoff vent (¾ in. or larger) should be open during the "lag" or coming-up period. The bleeders should be open throughout the process. There should also be an adequate drain in the bottom that can be used as a vent as well as drain. All cans should be coded.

A high temperature such as 248°F. requires less time than a moderate temperature such as 240°F., but it also damages the product more severely in case of a few minutes' overprocessing.

The character of the data presented in *Bulletin* 26-L may be seen from that given for white asparagus. The process time at 240°F. for 8-oz., No. 1, No. 1 Tall, No. 2, No. 1 Square, No. 2½ Square, No. 2½ Round, No.

1½ Flat, and Savoy-tip cans is 20 min. in all cases; and at 248°F. it is 12 min.

Agitating Discontinuous Pressure Sterilizers. This type of sterilizer has been developed in the sterilization of milk. It has been found that milk tends to scorch and curdle unless it is agitated during sterilization under pressure. The cans are placed in a cage inside the retort, and the cage is revolved during sterilization, keeping the cans constantly in motion and thoroughly agitated. The author is not aware that this sterilizer is used extensively for other products, although it would be undoubtedly of

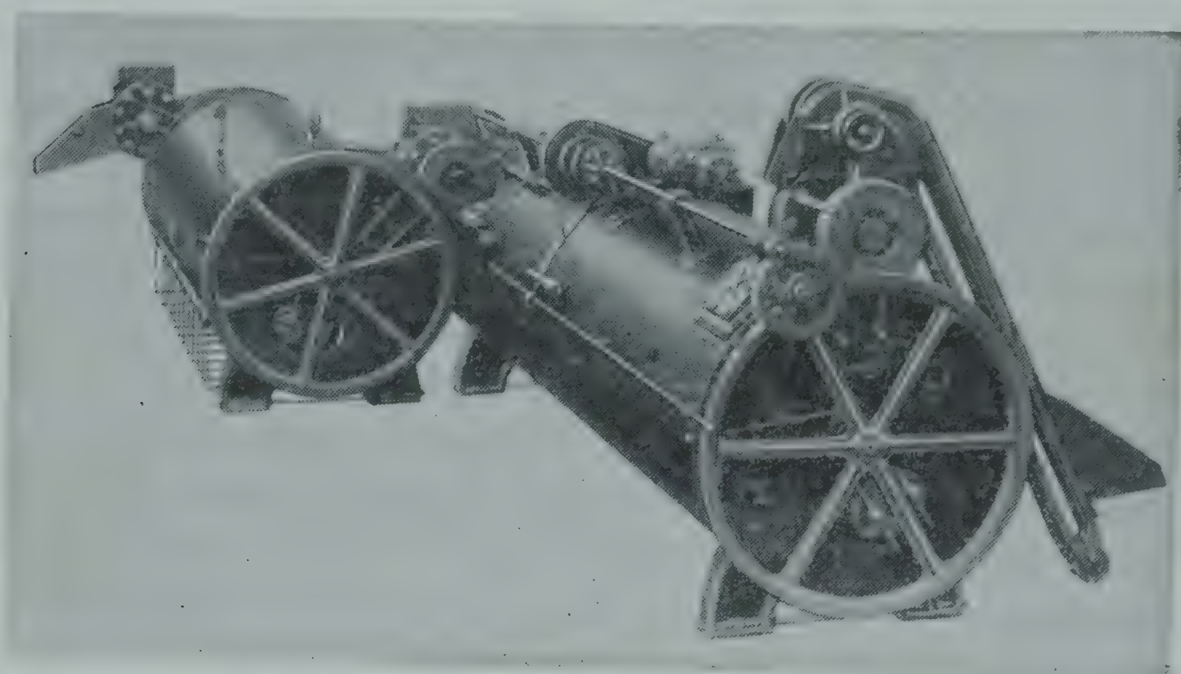


FIG. 33. Continuous agitating pressure processor for nonacid food products. (*Food Machinery Corp.*)

service in the sterilization of some vegetables. For canned milk it is being replaced by the continuous agitating sterilizer.

Continuous Agitating Pressure Sterilizers. During the past few years, cannery-machinery companies have perfected continuous agitating sterilizers built on the same general principle as the open agitating cooker. The principal difficulty had been the one of admitting the cans to the retort and removing them after sterilization continuously without affecting the steam pressure in the retort, but this difficulty has been overcome by the construction shown in Figure 33. Revolving can-shaped pockets carry cans into the retort and out without loss of steam. The cans are cooled in a separate compartment under pressure. It has been proved by Bigelow and others that a very much higher temperature and a correspondingly shorter time can be employed with the agitating continuous cooker, for the reason that agitation prevents overheating of the product in contact with the tin. This retort is particularly desirable for cream-style corn and spinach, since it greatly increases the rate of heat penetration, thereby making a shorter process time possible and reducing the danger of overcooking correspondingly. Its principal disadvantage is its high initial cost.

C. K. Wilson of Food Machinery Corporation (1953) has discussed the principles, use, and advantages of high-temperature short-time processing methods and equipment. With rather fluid products such as peas in brine which heat readily by convection in even a still retort, rapid agitation in a continuous agitating cooker increases the rate of heat penetration only moderately. With one of viscous condition such as canned cream-style corn which normally heats very slowly by conduction in a still retort, mechanical agitation greatly increases the rate of heat penetration by setting up vigorous convection currents. He calls this effect in such cases "induced convection heating." Very high temperatures, 270°F. or higher, can be used. They very greatly reduce the required process time and result in improved quality because the rate of damage to quality with increase in temperature is less than increase in killing effect on heat-resistant bacteria.

High-temperature short-time (H.T.S.T.) processes also greatly increase the capacity of the continuous agitating retort; they save as much as 60 to 75 per cent of the steam required in processing, as compared with still retorts; decrease the water requirement for cooling of cans; save the labor of from 7 to 15 men compared with that required for still retort operation of like output; and require only half the floor space needed for a vertical retort installation of equal output.

Kueneman (1953) points out that it also gives a finished product of more uniform quality, less damage to cans, and no stack burn from uncontrolled cooling and eliminates the elaborate records required in batch, still retort processing. There is no "come-up" period since the temperature is constant. It is now used in the J. R. Simplot Company plant in Idaho for cream-style corn with a process time of 12 min. at 275°F. for size 211 × 304 cans at 350 cans per minute and 18 min. at 270°F. for size 303 cans at 250 cans per minute. He states that a generous head space, ¼ in., at time of sealing the cans is required in order to give a "bubble" in the can contents, which very greatly increases agitation of the can contents. Also, the consistency of the cream-style corn must be adjusted and controlled within known limits by addition of starch free of thermophilic spores. The speed of can rotation in the retort must be high in order to induce adequate convection. This is attained by rapid rotation of the can-carrying reel inside the retort, which means rapid "put-through" of cans and short process time.

This procedure for cream-style corn is discussed further in the chapter on canning of vegetables.

Cooling after Sterilization. As soon as the contents of the cans have been thoroughly processed, it is essential that the can and contents be cooled immediately. At one time it was customary in some canneries to stack the cans on trays in large piles after processing. If the contents of the cans had

not been cooled sufficiently, cooking could continue in cans located in the interior of the stack. This might result in development of a dark color and overcooking of tomatoes and other vegetables and the development of "flat sours" in vegetables through the growth of thermophilic spore-bearing bacteria that survive the usual commercial sterilization process. However, canners now cool the cans to 110°F. or lower and often case them at once.

The cans should not be cooled to too low a temperature, for the reason that they will remain wet and become rusty. A temperature of 110°F. is high enough to dry the cans but not high enough to cause injury to the contents. Cooling is accomplished by sprays of cold water or by passing the cans through a tank of running cold water. In either system a large amount of water is needed. Cooling under sprays makes much more efficient use of the cooling water, since it takes advantage of the great amount of heat absorbed from the cans and contents by evaporation of water from the surface of the containers. This method of cooling has proved very successful in cooling canned orange juice, where extremely rapid cooling is imperative. The spent cooling water may be cooled by evaporative cooling tower and used repeatedly, provided it is chlorinated to a level that will prevent growth of spoilage bacteria. See section on chlorination at the end of the chapter.

A cooling device of the same general design as the continuous agitating sterilizer is shown in Figure 33.

The cooling process is sometimes completed by stacking the cans overnight in an open court, usually in such a manner that air currents may pass freely around the cans. This procedure is much less common than formerly, because of the extra labor cost.

Testing Vacuum of Cans. It is desirable that the canner have accurate information upon the degree of vacuum in the cans after sterilizing and cooling, because faulty sealing of the cans is very quickly detected by vacuum test. The simplest form of tester consists of a dial gauge equipped with a sharp, hollow tube and a large soft-rubber gasket. The sharp tube is inserted in the lid of the can by pressure, and the entrance of air prevented by the heavy rubber gasket. The vacuum may then be instantly read from the dial (Figure 24).

Another excellent vacuum tester is a bell jar (containing the can under water), which is subjected to a gradually increasing vacuum by means of a hand pump. Poorly sealed cans emit bubbles of air. When the vacuum inside the can and in the bell jar become equal, the head of the can bulges slightly. This vacuum tester is valuable in making frequent observations on experimental cans because the cans are not injured. A simpler and more rapid device has been introduced by the American Can Company and National Canners Association. A rubber washer is placed on the can. On the washer is placed a funnel attached to a vacuum line. Vacuum is applied until the lid of the can "flips." The corresponding vacuum is read

instantly on a gauge. While this reading is higher and more variable than obtained by vacuum gauge, it is useful for following the changes in vacuum in cans in storage or under incubation.

Canners a number of years ago tested the cooled cans by tapping with a short steel rod. Imperfectly sealed cans or "leakers" give forth a "hollow" sound, and perfectly sealed cans a "flat" sound. The method is simple, extremely rapid, and surprisingly delicate. An experienced workman rarely fails to detect faulty cans by this test.

Important Precautions in Retort Operation. As emphasized in *Continental Can Co. Bulletin* 19, 1950, certain precautions should be observed in using retorts.

The retort should be equipped with a temperature recorder–controller, and if it is a vertical retort, it should have a pressure gauge and mercury thermometer; if a horizontal retort, a pressure gauge and two mercury thermometers (one at each end).

The steam supply line which delivers steam to several retorts is called a "header." This must be large enough to meet the peak demand for steam. The main steam line from boiler to cookroom should be insulated to reduce loss of heat by radiation. According to the reference mentioned above, if three retorts are to be served, the header should be 3 in. in diameter. The steam inlet into the retort must be large enough to permit rapid coming up of pressure and temperature. For the same reason the regulating valve should be of adequate diameter.

A bypass valve, i.e., a manually operated valve for admission of steam in addition to that admitted by the controller steam line, is useful during the initial coming-up period. It *must be turned off*, however, after the retort is at desired temperature *because if left open the extra steam could blow up (burst) the retort.*

The steam spreader is an extension of the steam line into the retort and is perforated with holes to admit steam to the retort. The holes should be positioned in such manner and be of such size that a rapid rise in initial temperature can be secured and uniform temperature maintained throughout the retort during the holding period. A good rule is to make the total cross-section area of these holes equal to at least 1½ but not more than 2 times the cross-section area of the steam inlet.

For retorting of glass containers with water and air the vent used during cooling should be pressure-controlled in order to maintain constant pressure during cooling and thus prevent loss of lids from the jars. Steam vents used during the coming-up period must be large enough to "purge" the air from the retort quickly.

The water line and inlet used during cooling must be large enough to fill the retort quickly with water, otherwise some of the load will remain hot too long and be overcooked.

In California the retort operator must pass an examination given by the

State Board of Health cannery-inspection service and is then given a permit to operate retorts. The inspectors of this service check all equipment regularly, see to it that all lots are properly coded, and a temperature-chart record made and kept for every lot of nonacid food that is processed.

A very important precaution is to make certain that no basket or retort truckload of canned nonacid food is bypassed to the warehouse without being retorted. In some canneries a red card is hung on every basket of unsterilized canned foods as it is filled. When it is placed in the retort the card is removed.

All retorts are liable to fail (burst) if their critical steam pressure is exceeded. Old retorts are apt to have been weakened by prolonged use. Therefore, before each operating season, retorts should be checked to determine whether or not they are in safe operating condition. In some states such testing is mandatory and a renewable permit is necessary. For example, a retort to be operated at 15 lb. per sq. in. should be tested to 30 lb. per sq. in. Pressure gauges on the retort should be checked frequently.

As previously stated, all retort baskets and cars should be constructed to permit free passage of steam.

Safety valves of ample capacity are mandatory on all retorts. They should be tested daily to make certain that they are always in operating condition.

The process time should be based on the initial temperature of the coldest can in the retort. With some vacuum-packed products the coming-up time may have to be prolonged sufficiently to dispel the vacuum in the cans before allowing any rise in pressure in the retort; otherwise the cans may panel or collapse.

Chlorination of Cooling Water. The subject of chlorination of water for cannery use is more fully discussed in the chapter on sanitation.

Suffice it to say at this point that during cooling of the canned product in water there is danger of infecting the contents of the cans with spoilage organisms from heavily contaminated cooling water. Re-use of cooling waters results in a build-up of microorganisms. During the first few seconds of cooling the sealing composition in the can lid may be soft enough to allow a minute drop of water to be drawn in and infect can contents because a vacuum suddenly develops during rapid cooling.

Harris (*Continental Can Co. Bulletin* 13) recommends that under practical operating conditions 1 to 2 p.p.m. of free chlorine in the cooling water should be maintained, and in exceptional cases 3 p.p.m. may be required to reduce the bacterial count to a safe level. If the free chlorine content is too high, corrosion of the tin coating of the cans may occur.

Rough-handling Hazard. If the cans are "banged around" on conveyers or crushed slightly in the retort baskets or otherwise handled very roughly, can seams may be sprung (loosened) sufficiently to admit contaminated

cooling water or air, with resultant spoilage. This is particularly the case with larger cans such as No. 10. Obviously, such treatment must be avoided.

ASEPTIC CANNING

Martin has recently described the essentials of aseptic canning as follows:

> The process embodies a combination of the principles of short high-temperature sterilization and aseptic canning methods. It differs from conventional canning methods in that the product is quickly sterilized and cooled before it is sealed in the can. This is accomplished by pumping the product successively through the heating, holding, and cooling sections of a closed heat-exchange system. The product thus sterilized and cooled under pressure flows continuously from the heat exchange system to the aseptic canning machine in which it is filled and sealed in sterile containers without exposure to air or atmospheric contamination.

The early research and development work on this process was done by Dr. C. O. Ball and coworkers in research at the American Can Company in 1927. In recent years equipment and procedures for the industrial application of aseptic canning have been developed by W. McK. Martin and associates of the Jas. Dole Engineering Company. The W. F. and John Barnes Company of Rockford, Illinois, manufactures and installs the equipment.

Before starting canning operations, the heat-exchange equipment, pipelines, pump, and other handling equipment are sterilized by hot water under pressure at 300 to 325°F. The canning unit and can-sealing unit are sterilized by superheated steam at 400 to 600°F. and during operation are maintained in a sterile condition in like manner. Cans are sterilized in an insulated tunnel by superheated steam in the range of 400 to 445°F.; higher temperatures would melt the solder and tin coating of the cans. The lids are sterilized at the sealer by superheated steam just before application to the filled cans.

Conventional heat exchangers of tubular or plate types or rotary heat exchangers such the Votator can be used to heat the product to sterilizing temperature, and similar equipment can be used to cool the product to filling temperature, about 100°F. Between the heating or sterilizing unit and cooling unit is a holding unit, in which the product is held at the desired temperature for the required time.

The cooled, sterile product flows continuously under pressure to the can-filling mechanism. The filler consists of a rectangular enclosure through which the cans are conveyed continuously in a straight line beneath a slit-type filling nozzle. An atmosphere of superheated steam or other sterile,

inert gas in the filler, closing machine, and interconnecting conveyer system maintains sterility and prevents the entry of air-borne bacteria into the system.

At present the aseptic canning method is in use for fluid and semifluid food products but not for those of large particle size such as asparagus, fruits, whole-grain corn, beans, etc.; although it has been used successfully in the canning of cream-style corn.

The short high-temperature sterilization used in the process gives finished products of better flavor, color, and texture than an equivalent process at conventional lower temperatures. The product quality is the same for large as well as small containers, since the sterilization takes place in a separate part of the system and the product is canned cold. The short high-temperature method has very wide latitude between adequate sterilization and overcooking or scorching and thus provides a wide range of safety without danger of damaging the quality of the product, according to Martin. It permits close and accurate measurement and control of actual temperatures attained during heating, cooling, and holding. Since it is continuous and since a continuous automatic temperature-control chart is made during operation, there is no need to keep records of separate retort loads as there is with discontinuous still retorts. It is intended for use primarily with non-acid food products, such as milk, soups, sieved vegetables, and baby foods of low acidity; but it has been used successfully with orange concentrate, an acid product.

Radiation Sterilization. Radiation sterilization depends upon exposing food to an intense field of radiation for a sufficient time to destroy all organisms in the product capable of causing its spoilage. It has been called "cold sterilization," as the temperature does not rise appreciably during treatment. O'Donnell stated in 1956 that at that time 65 laboratories had research under way in this field in the United States. The Quartermaster Corps of the military department initiated a program on radiation sterilization in 1953, and at the present time (1957) is supporting about three-fourths of the research on this problem in the United States.

Radiations differ in various respects, but a very useful basis of differentiation is their respective frequencies expressed in cycles per second. Thus, infrared ranges from 10^{12} to 10^{14} cycles per second, visible light is in the range of 10^{15} cycles per second, ultraviolet 10^{16} to 10^{17}, soft X rays 10^{18} to 10^{20}, hard X rays, cathode rays, and gamma radiation 10^{21} to 10^{22}, and cosmic rays 10^{23} cycles per second. The higher the frequency, the greater is the penetrating power of the radiation.

The general unit of radiation dosage is the roentgen, and in food processing it is the "rep," an abbreviation of "roentgen-equivalent-physical." The roentgen and the rep are equivalent to the release of 93 ergs of energy per gram of material. All living organisms can be killed by ionizing radia-

tion. According to O'Donnell, insect eggs and larvae are killed by 50,000 to 70,000 rep, adult insects and pupae by 80,000 to 600,000, man by 300 to 500, yeasts and molds by 100,000 to 800,000, and spoilage bacteria in foods by 2 million to 3 million rep.

When radiation strikes a solid or liquid it may be reflected, transmitted, or absorbed. When visible light is absorbed it is largely converted into heat, as when sunlight strikes a black iron surface. When ionizing radiation, such as an electron beam (cathode ray), is absorbed, there is little or no rise in temperature; the energy is used to ionize molecules in the substance that is absorbing the radiation. If all the radiation is reflected or if all is transmitted, it is without effect on microorganisms. If all is absorbed, there is only surface action. Partial transmission permits penetration, and partial absorption permits the energy to be effective in killing microorganisms throughout the product.

X rays are produced when a stream of electrons strikes a metal target such as gold or tungsten, as occurs in an X-ray tube. About 95 per cent of the energy is transformed into heat, and only about 5 per cent into X rays. If a very powerful beam of electrons is employed, of 185 kv. or higher, hard X rays are produced and have great penetrating power. If one of only 100 kv. is used, so-called soft X rays are obtained. These have less penetrating power than the hard X rays.

Electrons are produced by several types of special apparatus. Proctor and Goldblith have used the Van de Graff electrostatic generator in much of their research on cold sterilization of foods. In this machine charges are carried from ground to terminal on a rapidly moving belt and the electrons accelerated down an evacuated X-ray tube at constant potential. The target of the X-ray machine is removed, and hence a beam of electrons instead of an X-ray beam is obtained. Electrons are also produced by the Capacitron of Brash and Huber, the cyclotron, the betatron, the linear accelerator, the proton synchotron, and the synchotron, according to Proctor and Goldblith. A beam of electrons is termed a cathode ray.

Gamma radiation, very similar to X rays in penetrating power, is given off continuously by radioactive elements, such as isotopes of various elements formed by bombardment in a nuclear reactor. Thus, radioactive cobalt 60 is formed in this manner by radiation of cobalt 59. It gives off both cathode rays and gamma rays. If it is placed in a glass tube, and this in turn in an aluminum tube; the cathode radiation is completely absorbed by the Al, and the gamma radiation is transmitted.

Other forms of radiation are less useful than X rays, cathode rays, and gamma radiation in the cold sterilization of foods. Neutrons often induce radioactivity in the treated product. Alpha particles have very low penetrating power, and their effect is principally on the surface. The same is true of ultraviolet, except in clear aqueous solutions. Infrared furnishes heat,

but has very little penetrating power. Its effect is due to heat transmitted from the surface.

Since the generation of X rays is so wasteful of energy it would seem logical to use the electron beam itself instead of the X ray generated by it. The electron beam (cathode ray) has somewhat lower penetrating power than X rays of similar power; nevertheless cathode rays generated by high electron voltages have fairly good penetrating power. Evans states that penetration into items of unit density is about ¼ in. per million electron volts when the item is irradiated from both sides.

Much of the research on cold sterilization, especially that conducted under the Quartermaster program, has been done with gamma radiation. One source is the spent rods of fissionable material from the Atomic Energy Commission's reactors. According to Evans, these will furnish 1 to 10 megareps per hr., or it would require about 25 min. to sterilize a can of food. In the experimental unit nine cans may be treated at a time. From the sodium-cooled reactor radioactive sodium of high intensity is obtained. In another reactor a blanket of indium sulfate is used and becomes an intense source of gamma radiation.

As the atomic-energy program expands, enormous quantities of radioactive waste will result and should provide a low-cost source of gamma radiation. However, its transportation is very troublesome and costly, as heavy shielding is necessary to protect those who must handle or be near the radioactive materials.

Not only must the food product be sterilized, but it must be in a germproof container. If processed in the container, the latter must be pervious to the radiation used but impervious to spoilage organisms.

Pratt and Ecklund state that 24 hr. of intense radiation by gamma rays from cobalt 60 in the University of Michigan apparatus was necessary for the sterilization of 211 × 300 size cans of meat products. In other words, radiation sterilization is very slow.

Gamma radiation is continuous, whereas electrons or cathode rays are generated only while the machine is in operation. At the levels of energy used in the radiation sterilization of foods with gamma rays and with cathode rays, the treated foods have not become radioactive and have been fed to laboratory animals and human volunteers without ill effect.

According to *Western Canner and Packer* the maximum thickness of food product that can be treated with X rays or cathode rays is about 5 in. provided that both sides are irradiated simultaneously.

Pratt and Ecklund state that pH value and added sodium ascorbate had little effect on the lethal effect of irradiation on bacteria or on flavor retention. However, irradiating meats in the frozen condition reduced the adverse effect of irradiation on flavor. A greater dose of irradiation is required for bacteria in broth than in water or in a food product. Enzymes require a

heavier dose, usually, than microorganisms, Similarly, some types of bacteria are more resistant than others.

Many foods when irradiated sufficiently for sterilization develop undesirable flavors and odors, in some cases becoming highly unpalatable or inedible. O'Donnell lists among the foods that have withstood irradiation well in respect to flavor the following: bacon, green beans, liver, broccoli, sprouts, carrots, chicken, pork sausage; among those that behaved fairly well, the following: apple juice, applesauce, beefsteak, cabbage, corn, ham, halibut, peas, hamburger; and among those that behaved poorly, the following: bananas, Lima beans, cheese, lemon juice, milk, orange juice, strawberries, tomato juice. Others have reported on this problem; for example, it is stated that at dosages used in killing insects (about 30,000 rep) there is no significant change in the food. For a detailed discussion of this subject see Morgan (1955).

Cost of equipment for the generation of electrons and X rays is high compared with that of retorts and other forms of heat-processing equipment. It is too early, as the *Western Canner and Packer* points out, to determine whether or not the cost of cold-sterilization methods can be brought within the practicable range. What the future holds for the development of radiation sterilization commercially is not yet discernible. It appears to be a case of watch and wait.

Antibiotics in Canning. Research on the effect of antibiotics on the death time and temperature of spoilage organisms has been done by researchers of the U.S.D.A. and of the National Canners Association. This subject has been presented in Chapter 1.

REFERENCES

Preservation by Heat

ANDERSEN, A. A., MICHENER, H. D., and OLCOTT, H. S.: Effect of some antibiotics on Clostridium botulinum, *Antibiotics & Chemotherapy*, **3**(5), 521–526, 1953.

BALL, C. O.: Advancement in sterilization methods for canned foods, *Food Research*, **3**(1, 2), 13–52, 1938.

———: Mathematical Solution of Problems on Processing of Canned Foods, *Univ. Calif. Pubs. Public Health*, vol. 2, 1928.

BALL, C. O. and OLSON, F. C. W.: "Sterilization in Food Technology," McGraw-Hill Book Co., Inc. New York, N.Y., 1957.

BENJAMIN, H. A., and JACKSON, J. M.: Right and wrong procedures in pressure cooling of cans, *Food Inds.*, **16**(5), 66–69, 135, May, 1944.

BIGELOW, W. D., BOHART, G. S., RICHARDSON, A. C., and BALL, C. O.: Heat penetration in processing canned foods, *Natl. Canners Assoc., Research Lab., Bull.* 16-L, 1920.

——— and CATHCART, P. H.: Relation of processing to the acidity of canned foods, *Natl. Canners Assoc., Research Lab., Bull.* 17-L, 1921.

CRUESS, W. V.: The home canning of foods, *Univ. Calif. Agr. Expt. Sta. Circ.* 158, 1915.

———, FONG, W. Y., and LIU, T. C.: The role of hydrogen ion concentration in the sterilization of non-acid vegetables, *Hilgardia*, **1**(13), 1925.

DICKSON, E. C., BURKE, G. S., and WARD, E. S.: A study of the resistance of the spores of Bacillus botulinus, *Arch. Internal Med.*, **24**, 581–599, 1919.

ECKLUND, O. F.: Apparatus for the measurement of heat penetration in canned foods, *Food Research*, **10**(7), 231–233, 1949.

ESTY, J. R., and MEYER, K. F.: Heat resistance of spores of Bacillus botulinus, *J. Infectious Diseases*, **31**, 650, 1922.

FOXBORO INSTRUMENT Co., Foxboro, Mass.: Circulars and catalogue of temperature recorders and controllers.

FROST, L. J.: Operation of retorts, *Continental Can Co., Research Dept., Bull.* 5, 1945.

HALLMAN, G. V., and STEVENS, R. G.: Sterilizing canned foods, *Ind. Eng. Chem.*, **24**, 659–662, 1928.

HICKS, E. W.: On the evaluation of canning processes, *Food Technol.*, **5**(4), 134–142, 1951.

HOWARD, A. J.: "Canning Technology," chap. 8, J. and A. Churchill, London, 1949.

IRISH, J. H., JOSLYN, M. A., and PARCELL, J. W.: Heat penetration in the pasteurizing of syrups, etc., in glass containers, *Hilgardia*, **3**(7), 1928.

JACKSON, J. M., and OLSON, F. C. W.: Thermal process times for canned foods. IV. Mechanism of heat transfer within the container, *Food Research*, **5**(4), 409–421, 1940.

KUENEMAN, R. W.: Continuous agitating retorts, *Natl. Canners Assoc., Tech. Sess. Proc.*, 1953, pp. 4–7.

LANG, O. W.: Thermal processes for canned marine products, *Univ. Calif., Pubs. Public Health*, **2**(1), 1–182, 1935.

MAGOON, C. A., and CULPEPPER, C. W.: A study of the factors affecting temperature changes during the canning of fruits and vegetables, *U.S. Dept. Agr. Bull.* 956, 1922.

MARSH, G. L.: Buffering action of non-acid vegetables, *Hilgardia*, **11**(7), 315–341, 1938.

MARTIN, W. McK.: Continuous aseptic process, *Food Eng.*, **23**(6), 67–70, 134–137, June, 1951.

MEYER, K. F.: The protective measures of the State of California against botulism, *J. Preventive Med.*, **5**, 261, 1931.

Minneapolis-Honeywell Regulator Co., Philadelphia: Booklets and charts on regulators of various types (temperature, pH, voltage, density, etc.)

National Canners Association Research Staff: Processes for non-acid vegetables. *Natl. Canners Assoc., Research Lab. Bull.* 26-L, January, 1930 (revised 1936 and 1954).

NICOL, W. C.: Safety at high pressures, *Food Inds.*, **17**(1), 83–85, January, 1945.

OLSON, F. C. W., and JACKSON, J. M.: Heating curves. Theory and practical application, *Ind. Eng. Chem.*, **34**(3), 337–342, March, 1942.

———, and STEVENS, H. P.: Nomograms for graphic calculation of thermal processes for non-acid canned foods, *Food Research*, **4**(1), 1–21, January–February, 1939.

PARCELL, J. W.: Investigations on the retorting of glass containers, *Canning Age*, June and July, 1930.

PILCHER, R. W., ET AL.: "The Canned Foods Reference Manual," 2d ed., chap. 2, Modern thermal process determination, pp. 297–321, American Can Co., New York, 1949.

Retort installation, equipment and operating procedures: *Continental Can Co., Research Dept., Bull.* 19, 1950.

SCHULTZ, O. T., and OLSON, F. C. W.: Thermal processing of canned foods. III. A special coordinate paper and methods of converting initial and retort temperatures, *Food Research*, **5**(4), 399–407, 1940.

SMITH, C. L.: Chlorination of cooling tank water, *Food Packer*, **28**(6), 32–34, 1947.

———: The relationship of spoilage to rough handling and contaminated cooling water, *Continental Can Co., Research Dept., Bull.* 9, 1946.

SOGNEFEST, P., HAYS, G. L., WHEATON, E., and BENJAMIN, H. A.: Effect of pH on thermal process requirements of canned foods, *Food Research*, **9**(5), 400–416, 1948.

SOMERS, I. I.: How to vent steam retorts to remove air hazard, *Food Inds.*, **16**(2), 80–83, 151–153, February, 1944.

Taylor Instrument Co., Rochester, N.Y.: Circulars and catalog of temperature recorders and controllers.

TOWNSEND, C. T., ESTY, J. R. and BASELT, F. C.: Heat resistance studies on spores of putrefactive anaerobes in relation to determination of safe processes for canned foods, *Food Research*, **3**, 323–346, 1938.

WILLIAMS, O. B.: Experimental procedures for process determination for canned foods, *Proc. Inst. Food Technologists, 1st Conf.*, 323–327, 1940.

WILSON, C. K.: Continuous agitating retorts [for cream style corn], *Natl. Canners Assoc., Tech. Sess. Proc.*, 1953, pp. 2–4.

Preservation by Irradiation

EVANS, COL. B. S., JR.: Current evaluation and future outlook of radiation sterilization sources, "Proceedings of Symposium on Radiation Sterilization of Foods," pp. 18–30, Q.M. Food and Container Institute, Chicago, June 10, 1955.

JACKSON, COL. W. D.: Status and prospects of radiation sterilization of foods, *Natl. Canners Assoc. Inform. Letter* 1570, January, 1956.

MORGAN, B. H.: A review of present knowledge of radiation effects on food items, "Proceedings of Symposium on Radiation Sterilization of Foods," pp. 18–30, Q.M. Food and Container Institute, Chicago, June 10, 1955.

O'DONNELL, A. J.: Atoms and apples: radiation sterilization of foods, *Stanford Research Inst. Rept.*, Menlo Park, Calif., Oct. 1, 1956. Mimeographed.

PRATT, G. B., and ECKLUND, O. F.: Radiation sterilization of foods, *Quick Frozen Foods*, May, 1954, p. 51.

——— and ———: Recent experiments in radiation sterilization of foods, *Natl. Canners Assoc. Inform. Letter* 1472, Jan. 30, 1945.

PROCTOR, B. E., and GOLDBLITH, S. A.: Electromagnetic radiation fundamentals and their applications in food technology, pp. 119–197 in E. M. Mrak and G. F. Stewart (eds.), "Advances in Food Research," vol. 3, Academic Press, Inc., New York, 1951.

——— and ———: Effect of supervoltage cathode rays on the bacterial flora of spices and other dry food materials, *Food Research*, **15**, 490–493, 1950.

Radiation sterilization of foods, *Western Canner and Packer*, **47**(7), 17–21, June, 1955.

CANNING OF FRUITS

The commercial canning of fruits has increased rapidly during the present century, particularly on the Pacific Coast of the United States and in Hawaii. Australia also is vigorously developing its fruit-canning industry, in some cases under government subsidy and supervision.

General. The use of fruit varieties especially suited to canning and the careful observance of established commercial size and quality grades are the two most important fundamentals in the successful commercial canning of fruits. Ungraded canned fruit is unattractive in appearance, is uneven in color, texture, and maturity, and is not a product that will command a high enough price to return a reasonable profit to the canner and the grower.

The fruit must be gathered at the proper stage of maturity for canning; i.e., it usually should not be so ripe or so soft as that for eating fresh, yet it should have attained the flavor characteristics of the ripe fruit.

The fruit should be picked carefully and transported to the cannery quickly without bruising.

Boxes must be clean and must not be permitted to become moldy and heavily impregnated with fermented and soured fruit juice or pulp. Painting the boxes with a special coating, such as Cellu-san, to preserve the wood and prevent molding is common practice.

A clean factory operated with strict observance of the fundamental principles of sanitation is essential to the production of canned fruits of high quality.

Lighting. In the canning of fruits and vegetables proper lighting is essential throughout the plant, but particularly for such operations as inspection of empty glass containers, sorting of prepared fruits and vegetables, inspection, operation of peeling machines, hand filling of cans, and the operation of can sealers, sirupers, automatic can-filling machines, corn huskers, and corn cutters. A comprehensive report (1950) by the Committee on Lighting in the Canning Industry will be found very useful in planning cannery lighting arrangements. The report is based on information from several sources, one of the most important being the research conducted at Stanford University by D. C. White, cannery-lighting research fellow,

under the direction of Professor L. H. Brown (see references at end of chapter).

In the Committee's words, better lighting means not merely a bigger lamp but adequate light of better quality, directed where it is needed, with better diffusion, less glare, and with less contrast between the brightness of the task and the comparative darkness of the surrounding area.

Light is reported in terms of "foot-candles," "lumens," and "foot-lamberts." A lumen is the unit of light flow; e.g., a 100-watt incandescent lamp emits 1,620 lumens. One foot-candle is equivalent to one lumen of light per square foot. Foot-lambert is a unit of brightness. A surface emitting or reflecting one lumen per square foot has a brightness of one foot-lambert.

The lighting system in a cannery will require careful planning by an experienced lighting specialist who must see to it that wiring is properly designed and of ample current-carrying capacity, that it is safe and flexible, and that switches, control panels, outlets, etc., are properly selected and installed.

In general the artificial lighting in a plant should be designed to continue the level of natural illumination close to the windows in order to ensure good lighting over the entire area. The level of illumination obtained during the day will usually be considerably higher than that obtained at night. Therefore it is desirable to supplement failing daylight in late afternoon with artificial lighting to facilitate transition to night lighting.

In some areas in the cannery only general illumination is required; in others, sufficient to permit a high degree of visual acuity; i.e., the ability to distinguish fine detail is required in order to detect blemishes or to separate pieces of similar shapes or colors. The lighting should permit speed and accuracy in order to increase production, reduce costs, and permit comfortable seeing so as to avoid fatigue. It should be sufficiently intense to promote clean and sanitary conditions, high grade of product, efficiency, a low accident rate, and generally pleasant working conditions.

Good lighting should exist throughout the large working areas to permit safe and rapid movement of personnel, lift trucks, conveyers, etc.

In order to minimize eye strain there should not be too great a difference in the intensity of illumination between that of the objects being examined or handled and of the surroundings such as walls, machine parts, etc.

Colors for general use such as of walls, belts etc., should be fairly light. Large areas of strong colors such as red, yellow, or green should be avoided. Very light grayed tones should be used on walls and other general surroundings.

Workers who are middle-aged and older usually have lower visual acuity than younger persons; hence they will do better work in sorting, inspecting,

and other critical tasks if the candlepower is stepped up somewhat above that found adequate for young workmen.

In the warehouse where the cases or cans of finished product are stacked very high, lights should be so placed as to thoroughly illuminate the corridors between the stacks for safety and efficient operation.

Foot-candles of light that would be adequate for a good reflecting surface such as a new, white sorting belt are apt to be insufficient for dark surfaces. Thus, white paper under the same illumination has four times the reflectance of cast iron (80 per cent reflectance versus 20 per cent).

Deficiency in lighting is often due to glare or excessive differences in brightness. Adjacent light and dark areas are undesirable. Machinery and other solid objects stand out more sharply if there are some shadow effects, but harsh shadows should be avoided.

Usually supplementary, i.e., additional, lighting is needed for specific tasks such as sorting, pitting, etc., although general lighting of the entire area and supplementary lighting are of course interdependent. The Committee previously cited recommends that general illumination should never be less than one-tenth of the supplementary or specific task level; and in some cases the ratio may have to be 5:1 or less. As a general guide Walsh (1946) recommends that for even illumination of a given area the distance between light fixtures should not exceed the mounting height above the floor, and mounting height should be not less than 10 to 12 ft. above the floor.

Low surface brightness is desirable in lamps used for general lighting. Fluorescent lamps usually have lower surfaces brightness and provide better diffusion of light than other light sources. Lights that are within the usual field of view of the workmen should be shielded sufficiently to prevent direct view of the light-emitting source.

Lighting equipment in a cannery usually becomes dulled with use and should be washed occasionally, a good rule being to wash when the illumination has dropped to 70 per cent of its initial value. Lighting units should be so constructed that lamp and reflector can be removed easily and quickly for washing or replacement of the lamp.

The cannery should have and use frequently an accurate light meter. Such instruments are not unduly costly and are simple in operation.

The light measurement must be made at the point of and in the plane of the seeing task, whether it be horizontal, vertical, or at an intermediate angle.

Supplementary lights to illuminate a specific operation should be placed at such a level that they do not shine directly into the operator's eyes, or be shielded so that this objection is avoided. Out in the bright sunshine the intensity may be 10,000 foot-candles, and in the shade of a tree, 500. Near a

window indoors it may be 200 foot-candles, but it decreases so rapidly with distance from the window that artificial supplementary lighting becomes necessary.

Full advantage should be taken of daylight as a source of illumination in the cannery. Vertical windows on side walls are best for lighting vertical surfaces, and roof windows for lighting other surfaces. Candle power of the daylight transmitted through a window very rapidly diminishes with distance from the window. It might, for example, be adequate for a certain operation at 3 ft. from the window, but much too dim at 25 ft. Saw-tooth roof construction with vertical or steeply sloping windows is often used to supplement daylight from wall windows. Horizontal or gently sloping roof windows soon become coated with dust and grime and then transmit little light. They should be vertical or have a steep slope. If the general illumination is to be 30 foot-candles with an average sky brightness of 1,000 foot-lamberts, the total area of the windows should be at least 25 per cent of the floor area, according to the Committee on cannery illumination. The inside surfaces of windows become dulled by deposition of grime and dust, therefore must be washed occasionally if they are to be of much value for transmission of daylight.

The cannery illuminating Committee recommends the following intensities of general illumination: receiving and dispatching, retort and exhaust-box areas, can unscramblers, dining room, stairways, and rest and washrooms, 10 foot-candles; preliminary sorting, washing raw materials, cutting and pitting, canning, siruping, seaming and labeling, 20 foot-candles; machine shop, 30 foot-candles; laboratory, 30 to 50 foot-candles.

Supplementary-illumination requirements cover a wide range of light intensities and numerous operations. Only a few will be given as illustrations.

For cutting and pitting of apricots and peaches the illuminating Committee recommends 30 to 35 foot-candles of illumination. Sorting and canning operations for peaches and apricots require critical inspection, therefore 85 to 125 foot-candles of illumination is recommended. For critical color sorting, "daylight" fluorescent lamps are reported to give the greatest color difference on the surface of pieces of different maturity. For tomato-canning stations lighting should provide an 80 foot-candle level, and for sorting tomatoes for juice production it should be 100 foot-candles. As ripe olives are black or dark brown in color, lighting requirements for sorting and canning are high; the Committee suggests 125 foot-candles for this operation.

Limitation of space will not permit further discussion of canning lighting. The reader should consult the references on this subject given in the bibliography for further information.

Canning Season for Fruits and Vegetables in California and Hawaii. The fruit-canning season starts in California with cherries in May and ends with tomatoes in November (Figure 2).

PEACHES

(Prunus persica)

A larger quantity of peaches is canned than of any other single fruit, although pineapple is now a close rival. Its delicate flavor, which persists after canning, its firm texture, which permits sterilization without disintegration, its attractive appearance, and its moderate price have combined to give the peach its present popularity.

Varieties of Peaches for Canning. Peaches for canning by usual procedures should be of large uniform size, of symmetrical shape, of yellow color, of close tender fiber, not coarse or ragged, and of good cooking quality; i.e., they should retain their form, size, flavor, color, and aroma during sterilization in the can. The pit should be small in order to give thick halves that do not flatten during heating. The fruit should ripen evenly from the surface to the pit and should not be softer at the pit than at the surface. The flesh in the pit cavity should be yellow, not red, since red becomes brown after canning. Some varieties retain their fresh flavor well or improve in flavor on heating after canning; others acquire a disagreeable flavor on heating, this being particularly true of some freestone varieties.

In general, the firm, yellow clingstone varieties grown in California for canning possess the qualities enumerated above, whereas most of the freestone varieties lack one or more of these desired characteristics. Most of the varieties of clingstones used for canning are inferior to most freestones in flavor. On this account consumer interest in canned freestone peaches has increased in recent years, and if canners properly take advantage of this trend, it should be possible to greatly increase the pack of canned freestones. Some canners are featuring a "ragged" pack of freestone peaches, advertising the fibrous appearance of the freestone as a virtue. Its lack of flavor is the clingstone's chief defect, a fact that undoubtedly accounts for much of the increase in popularity of its chief competitor, canned pineapple.

Three types of canning clingstone peaches are grown in California, viz., the Tuscan, an early variety, the Midsummer group of several varieties, and the Phillips, a late variety. The Midsummer varieties are considered superior to the Tuscan and Phillips in canning quality.

The Tuscan (sometimes called Tuskena) is an early large variety, ripening in California from about July 15 to about Aug. 1. Its principal canning season follows immediately that of apricots. It has a rich flavor, and its texture after canning is satisfactory. Its defects enumerated below, how-

ever, are so serious that it is rapidly becoming obsolete as a canning variety. Its flesh near the pit is red in color, a desirable property in a fresh fruit; but on heating, the red color becomes an unattractive brown. The pit is very large; consequently, after pitting, the halves are thin and become flat in outline on heating. Many of the pits split, making it difficult to halve and pit the fruit economically without marring the flesh. It is the only important early-ripening variety, and there is great need for another early variety of better quality to replace it. Plant breeders and horticulturalists are attempting to develop such a variety by crossing and selection. Two such varieties in commercial use are the Fortuna and the Shasta. Both are of good quality and ripen 2 to 3 weeks earlier than the Midsummer varieties.

Four to six weeks elapse after the close of the Tuscan season before the opening of the Phillips season. Consequently, canners require Midsummer varieties in order to permit a long canning season. There are many such varieties available. Of these the Paloro (also spelled Pelora) is one of the most important. It is of large size and rich flavor, firm, with small pit and symmetrical shape. The tree is subject to rust, a fungous disease, and much of the fruit drops as it approaches maturity. Aside from these defects it is a very good variety, being decidedly superior to both the Tuscan and Phillips in flavor and general canning quality.

The Hauss resembles the Tuscan somewhat in outward appearance and the Phillips in appearance after canning although it is much superior to the latter in flavor. The skin carries considerable pink color.

The Sims ripens toward the end of the Midsummer season. It is large in size and gives a large proportion of Fancy and Choice grades. It is of good canning quality.

The Orange is an old Midsummer variety, once popular for canning, but at present available in small quantities only. It has a highly colored skin and yellow flesh. The pit is large.

Other Midsummer varieties are the Walton, Halford, Gaumes, Libbee, and Peaks.

The Phillips cling is a late variety, ripening in September. It ripens over a longer period than the Midsummers and may be left on the tree longer than other varieties without deterioration in quality. The skin is usually free of pink color, and the flesh is deep yellow rather than orange-yellow. It is very firm, ships well, and cans well. However, it is lacking in flavor and is very variable in size, much of the fruit being too small for canning. It is decreasing in popularity in comparison with the Midsummer varieties. The University of California and the Canners' League are developing several late varieties to replace the Phillips and Levi as well as improved Midsummer varieties. R. O'Neal of the F. M. Ball Company of California mentions the following newer varieties as having been canned in 1956: Zolezzi, Stanford, Sutter, Peterson, Carolin, Stewart, Sullivan, and

Gomez. He states that the last seven varieties ripen late. Several appear to be promising in respect to suitability for commercial canning.

The Levi is a very late clingstone of poor flavor, large pit, and poor color. The Sellers, a late cling used in Australia, has been grown in California, where it is not considered of so desirable a canning quality as the better Midsummer varieties.

Several freestone varieties have been used for canning. Of these the Lovell is one of the best for canning, owing to its firm, fine texture, yellow color, and pleasing flavor. It retains its flavor well in canning.

The Elberta is grown in California and elsewhere primarily for table use. It is of large size; the skin is highly colored; the flesh is deep yellow except near the pit, where it is red. It is ragged in appearance but of very pleasing flavor after canning. The J. H. Hale resembles the Elberta in color and canning quality.

The Muir is the most important of the varieties used in California for drying. Its dry, mealy texture makes it unsuitable for canning. The Crawford and Salway have been canned but are not very satisfactory for the purpose.

The shipping varieties of peaches grown in Georgia have not been found very suitable for canning purposes, except for Pie fruit, because the color is not desirable and because the fruit softens badly during canning.

Of the varieties adapted to the Eastern states, the Elberta seems to be the most popular for canning.

Picking and Shipping Peaches for Canning. Peaches for canning purposes should be picked when of maximum size and at the firm-ripe stage of maturity. Great care must be used in order to avoid bruising. The lug boxes should not be overfilled, and the ends should be protected by cleats so that the fruit will not be crushed when the boxes are stacked in the car or truck.

Most of the peaches used for commercial canning in California are grown with irrigation in the great interior Sacramento and San Joaquin Valleys. Yields are heavy, and canning quality is good. The canning clingstone peach is of large size, deep yellow color, and of very firm texture. Because of its firm texture it withstands picking and shipping much better than do the freestone varieties. The skin is of "stick-tight" type and cannot be loosened or removed by steaming, in this respect differing radically from most freestone varieties.

Since 1937 the commercial canning of clingstone peaches in California has been regulated by the provisions of the California Agricultural Marketing Act of that year. It has been approved each year by the growers and the canners and is administered by the state director of agriculture in cooperation with the Cling Peach Advisory Board. Decisions are made by a committee made up of growers and canners. Under the Act, if it should be deemed advisable in any given season, the size of the pack may be limited to

certain specified number of cases, each canner being assigned a quota sed on his past packs. Such action is only taken in years of heavy producon and impending surplus of canned product.

The peaches are picked under the general supervision of field men of the rious canneries, with, of course, the cooperation and approval of the ower. Often the picking is done by contractors who furnish and pay the lar; the canner furnishes the lug boxes in which the fruit is placed at the chard and in which it is transported to the cannery. Transportation is iefly by truck, although some twenty years ago well-ventilated freight rs were used in shipping much of the fruit. The boxes are stacked on llets, and the pallets of boxes stacked on the truck by lift truck in some ses; in others they are stacked by hand on pallets resting on the truck or. Canneries in some districts are near the orchards, requiring a trip of ly 5 to 10 miles; but some are at considerable distance, 50 to 150 miles. n long hauls there is considerable loss in weight due to evaporation of oisture from the fruit, and some additional loss due to the same cause curs during storage of the fruit at the cannery before canning. Leonard al. (1955) report that the average loss during trucking of Halford cling aches from the orchard to the College of Agriculture at Davis, Calirnia, a distance of about 60 miles, was 1.4 per cent and 1.3 per cent during orage overnight, a total loss of 2.7 per cent. These are probably lower sses than occur under some commercial conditions where the distance om the orchard to the cannery happens to be greater than in this case and e average storage period at the cannery before pitting may be greater.

The fruit is picked at a stage of maturity that the canner and the ower deem optimum in so far as other conditions permit. The usual inimum size of cling peaches accepted for canning is 2⅜ in. in diameter. ne pickers are furnished rings of this diameter with which to occasionally eck the diameter of fruit that appears to be near the minimum diameter.

A fixed charge per ton of fruit canned is made to cover the cost of adversing the canned product by the Advisory Board, inspection of the fresh uit at shipping point near the orchards, and for administering the Act by e Board and the director of agriculture. Inspection of the fresh fruit is ade at stations located in each of the peach-producing districts. Several xes of fruit are taken from each load as samples. The fruit is size-graded determine the per cent of fruit below 2⅜ in. in diameter and critically spected for quality. If the percentage of undersize and poor-quality fruit ceeds a specified limit, the load is returned to the grower for sorting. umber 1 peaches for canning at present, in addition to being 2⅜ in. or ore in diameter, must be free of blemishes, must be of proper maturity, ust give two perfect halves from each fruit, and must be of good canning ality in other respects. The fruit should not be immature or overripe, ould be free of bruises, free of, or not include, many split-pit fruits, free of

gummosis, mildew, San José scale (an insect), other insect damage, cracks, sunburn, limb rub, excessive spray residue, and rot. The flesh around the pit must be free of black color. Undue delay in delivering the peaches to the cannery or in canning them after delivery to the cannery will result in deterioration in quality.

If the fruit must be held several days or longer for canning, it is placed in cold storage at 32 to 36°F. It should not be cold-stored longer than 2 weeks as it deteriorates in flavor in storage although it will retain its texture for a much longer period.

Leonard et al. (1955), in a report on extensive pilot-scale canning tests, state that the ratio of per cent by weight of soluble solids as determined by refractometer to total acidity expressed as citric acid monohydrate is a good measure of the maturity of the peaches for canning. If this ratio, S.S./A., is above 25 and the total acidity is below 0.5 per cent, the canned fruit will be of high flavor and color, qualitywise. The fruit examined in their experiments ranged from an S.S./A. ratio of 16.56 early in the season to 36.30 toward the end of the optimum picking season. The total acidity at first picking was 0.809 per cent, and at the tenth picking, 0.415 per cent. The experiments were made with peaches of the Halford variety from the Marysville district, California. It is possible that the optimum ratio for other varieties or of fruit from other districts might differ slightly from that of the conditions of the experiments mentioned above. The texture of the peaches was measured by a Ballauf fruit pressure tester, which is used for testing the maturity of pears for fresh shipment or canning. While it gave a general measure of the maturity of cling peaches, it was regarded as less reliable than the S.S./A. ratio.

Soluble solids and total acidity were determined on a sample of purée made of several samples of pitted peaches taken so as to represent a fair sample of the delivery. A Waring-type "blendor" was used to convert the sample into a fine-grained purée.

Annual Pack. The total pack of canned peaches in California, according to the *Western Canner and Packer*, was 23,420,000 cases in 1953, 20,042,000 in 1954, and 25,311,000 cases in 1955. Of these totals freestone peaches constituted about 4,500,000 cases on the average; the balance was clingstones. Under a state marketing order, as previously mentioned, the size of the pack can be regulated within certain limits. The agreement is between the growers of clingstone peaches, the canners, and the California State Department of Agriculture, Bureau of Markets. The State Department has the power of enforcing the provisions of the agreement or marketing order. The cling-peach advisory board with funds collected from the growers and canners promotes the marketing of canned cling peaches by advertising and other methods of sales promotion. Its activities are a part of the marketing order.

Receiving. On receipt at the cannery, the fruit should be graded roughly ccording to maturity and variety by segregation of boxes. The receiving oom should be cool and well ventilated. Most canners empty the boxes on conveyer that takes the fruit to the pitters.

In some canneries a large sample of each shipment of fruit is carefully orted to determine the relative amounts of the different grades present, nd the grower is paid accordingly. The peaches are usually graded for size efore pitting, since each machine is usually adjusted for peaches of pproximately one size.

Cutting and Pitting. The first operation in the canning process is that f halving and pitting. This work was formerly done by women by hand or y machine. Practically all cling peaches in California are now pitted by achine. Freestone peaches are pitted by machine unless peaches with plit pits are numerous.

Formerly, cutting tables were used. These were of various sizes and esigns. In most canneries at present the lug boxes of fruit are dumped utomatically by machine on a belt that delivers the fruit to the women perating the machines.

Large California canneries are equipped with belts: one to deliver the rm fruit to the peeling machine, one to care for the Pie grade of fruit, nd one to carry away the pits. Some small canneries may not be equipped ith belts; and the pits and refuse are thrown into buckets or dishpans, which are periodically removed.

Cutting and Pitting by Hand. A fruit-cutting knife is used to cut the ling peach around the suture from the surface to the pit. A spoon-shaped nife is then inserted from the stem end of the peach, and with this instrument the flesh is cut from the pit. Hand pitting of clingstone peaches is no onger done in commercial canneries. Freestone varieties are halved, and he pit is then easily removed with the cutting knife.

The women who do the cutting of freestone peaches also trim the fruit nd do a reasonable amount of sorting for quality. Thus Pie-grade fruit is egregated from the better grades to some extent.

Cutting and Pitting by Machine. In one of the early pitters (Food Machinery Corp.) the peach was placed suture up and forced by hand beween knives that faced each other and rotated so that as the peach was arried toward the pitting blade it was cut to the pit. A crescent-shaped nife then carved its way around the pit, separating the two halves from the it. The halves and pits were separated by a screen that allowed the pits to ll through but retained the halves; the halves were then conveyed to the ye peeler, and the pits to the waste bin. In the current improved Food Iachinery Corp. pitter the peaches are placed one by one on each of two hain-type conveyers which carry them to the pitting machine installed on platform above and in front of the two operators who feed the conveyers.

The peach and the pit are sawed in half, and the pit halves are removed by special crescent knives (Figure 34). Pits and halves of fruit are separated by screening. In the old Federal pitter also the pits were cut in half by saw, and in the early F. and P. (Filice and Perelli) pitter they were cut in half by a powerful knife ("guillotine") and pitted by crescent knives.

Recently the F. and P., or "Filper" (Figure 35), pitter has been re-

FIG. 34. Two-station cling-peach pitting machine. (*Food Machinery Corp.*)

designed to eliminate the "guillotine" and pitting knives. The peach is firs cut around the suture by machine. Then the two halves in the tight grasp of two cups are rotated in opposite directions to free them from the whol pits. Fruit halves and pits are then separated by screen. The pit cavity ha a slightly roughened surface that resembles that of a freestone peach Yield of halved fruit, and hence of the canned, is reported to be larger tha by other methods of pitting. The pitted halves are conveyed cup down on screen conveyer through a spray-type lye peeler in which the lye solutio wets only the outer, or skin, surface and not the pit cavity. In this way th

attractive, naturally rough surface of the pit cavity is retained and loss of flesh by lye action in the cavity is avoided. It is claimed that peaches that have been pitted and peeled in the foregoing manner have a superior flavor. The principal pitter that separates the halves from the pit by twisting is known as the "Filper torque" pitter. It was the first pitter using the twist, or torque, principle. Another machine using this method has appeared.

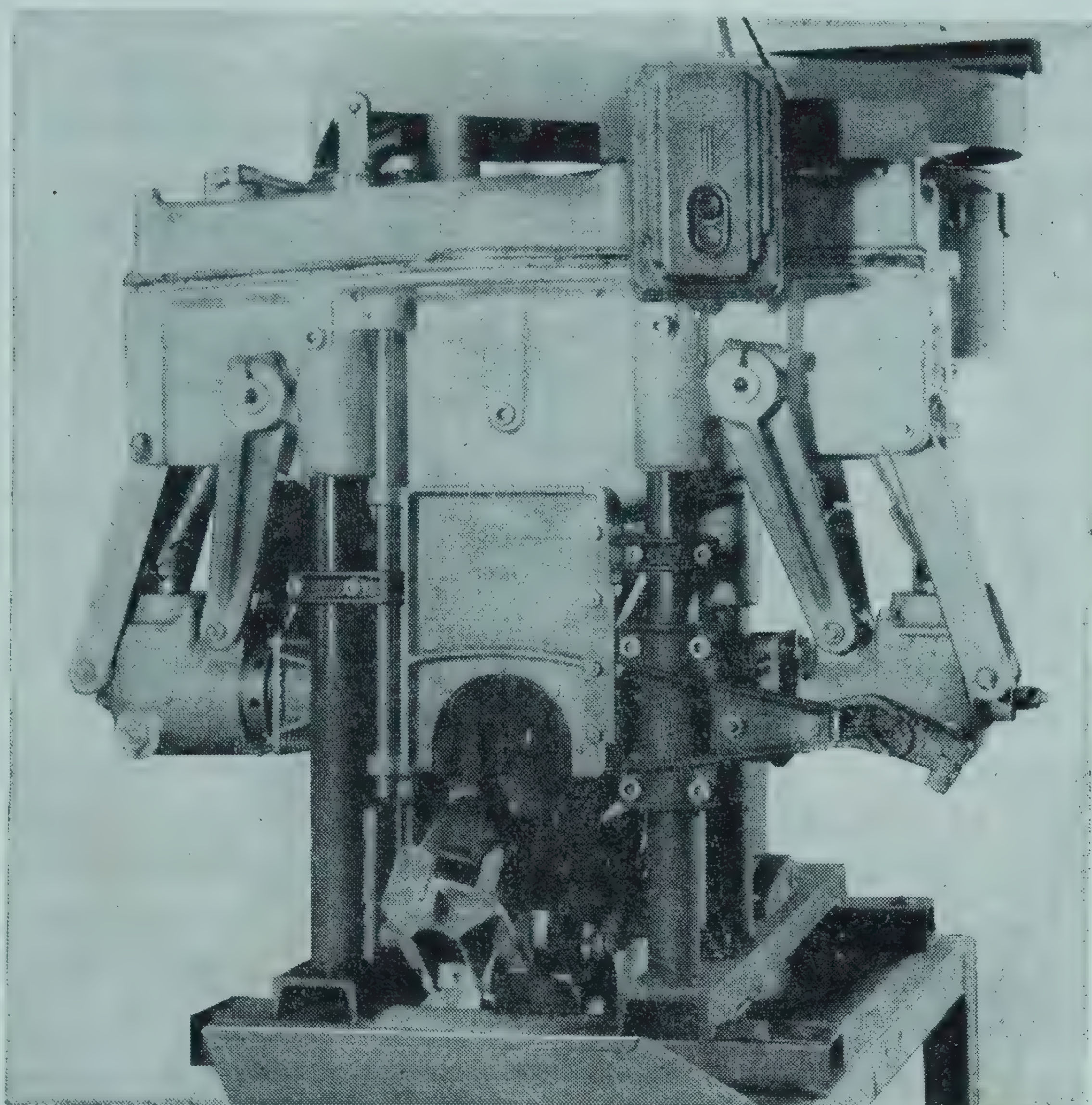


FIG. 35. Filper torque pitter for clingstone peaches. (*Filice and Perelli Co., Richmond, Calif.*)

More than twenty-five years ago a pitter in which parallel piano wires were forced into the peach, moved around the pit, and separated the peach into pitted halves was introduced from Australia. Several large canneries are successfully using an improved model of this wire pitter. It is supplied by the Ballou division of the Atlas Imperial Engineering Company and is commonly known as the Atlas pitter. It produces smooth pit cavities as contrasted with the rough surface in the cavities of halves of fruit pitted by the torque pitter.

Peeling. In California the halved peaches are peeled by treatment with hot lye solution, as described in Chapter 3. The concentration of the peeling solution is normally between 1 and 2½ per cent, and the length of application 30 to 60 sec. Green fruit requires a stronger solution than ripe fruit. In the Dunkley peeler the hot lye is applied as a spray to the fruit as it is

carried through the peeling compartment on a metal-cloth conveyer. The lye sprays can be applied from both below and above the draper or from above only. The lye is circulated by pump and is heated by steam. In another well-known peeler the peaches are carried through a tank of boiling lye solution by a revolving drum. In others a bucket or chain conveyer with broad baffle plates carries them through a tank of boiling lye solution.

The concentration of the lye is maintained by adding concentrated lye solution or the dry flake caustic (flake NaOH); such addition is necessary because dilution and neutralization of the lye reduce its strength rapidly. The operator judges when lye addition is needed by observing whether the fruit is well peeled or not. In many plants the solution is titrated frequently with standard hydrochloric acid, and an attempt is made to maintain a fairly constant concentration; in others the desired concentration is maintained by an automatic controller dependent on the conductivity of the solution, which varies with the NaOH concentration. Ordinary 60-cycle 110-volt current is used in the controller circuit. It passes through the solution between iron electrodes and opens a magnetic valve that admits concentrated NaOH when the concentration drops below that for which the controller is set. Most canneries buy lye (NaOH) as a 50 per cent solution and store it in a large metal tank from which it is pumped as needed.

If the solution is too strong, too much of the flesh is removed, entailing excessive loss in weight and decrease in diameter of the fruit. If it is too weak, the fruit is imperfectly peeled and much hand trimming becomes necessary; hence the advisability of close control of concentration.

The lye tank should be emptied at the end of each day's operations and refilled with fresh solution.

The fruit should be carefully sorted as to ripeness before peeling, since green fruit is much more difficult to peel than ripe and should receive a stronger solution.

Leonard et al. (1955), using industrial-scale equipment, found that the loss in lye peeling by applying the solution to both surfaces of the fruit ranged from 11.64 to 14.92 per cent, whereas it ranged from only 8.69 to 12.02 per cent by the cup-down method of application in which the lye solution is sprayed on the upper (skin-surface) side of the fruit.

Washing. The Dunkley patents for many years prevented the use (except in the Dunkley peeler) of sprays in washing the lye-treated fruit to remove skins and excess lye. At present, however, the use of sprays is general. The fruit is spray-washed on a metal-cloth draper or in a revolving metal drum. The sprays must be ample in volume and of high pressure in order to "cut" the lye-softened tissue from the pit cavities and outer surface. If this tissue is not removed, it becomes brown or gelatinous in the canned product. Severe washing also is necessary in order to remove adhering lye completely; if this is not done, the surface darkens rapidly.

Research conducted by P. J. Quin at the University of California showed that dilute (0.25 to 0.50 per cent) hydrochloric acid or dilute citric acid could be used to advantage as a rinse following washing. The dilute acid increases the acidity at the surface and thereby inhibits browning. The chloride ion is also a powerful oxidase inhibitor; hence hydrochloric acid is a much more effective preventative of darkening than is citric acid.

Blanching. From the washer the peeled peaches are often heated a short time in hot water or steam to remove final traces of lye and to partially inactivate the oxidase responsible for browning of the surface. Quin found that a temperature of at least 175°F. is necessary to cause much oxidase inactivation in the usual short period (1 to 2 min.) of blanching; and that about 10 min. was required to heat the half completely through. Often when halved peeled peaches are sliced for packing in that form, unattractive crescent-shaped brown areas will be evident at about 1 to 2 mm. below the surface. The browning is located at the line of demarcation between the flesh that has been heated sufficiently to destroy the oxidase and the unheated flesh near the center of the half. It is due to oxidasic browning and appears only after the fruit has stood for a considerable period. Prevention lies in either heating the fruit completely through blanching, replacing blanching with an acid rinse, omitting blanching, or canning promptly after blanching. If the peeled peaches do not darken rapidly, and if canned very promptly after peeling, blanching may be omitted.

Amount of Lye Used. T. Douthit, in a survey made several years ago, found that the amount of lye required varied from about 6 to about 15 lb. per ton of green fruit, according to type of peeling machine and the variety of peaches used. In one large cannery about 7 lb. of 95 per cent sodium hydroxide was required for each ton of peaches peeled.

Steam Peeling. Some varieties of peaches, especially when thoroughly ripe, can be peeled by subjecting the fruit to live steam for about 1 min. and then chilling with sprays of cold water. The peels can then be slipped from the fruit with the fingers.

Loss in Peeling. The loss in lye peeling of peaches varies greatly. In a test made by the author the loss was about 12 per cent with a spray type of commercial lye peeler. See recent data of Leonard in an earlier section which showed low losses in lye peeling by the cup-down method.

Sorting. The peeled fruit passes from the lye peeler or blancher on a slowly moving belt from which the sorters remove blemished, partly peeled, broken, and other unfit pieces. The prime fruit travels to the size-grading machine, and the Pie-grade fruit is sent by separate conveyer directly to the Pie-fruit department without size grading. If the fruit requires it, Pie-grade fruit is trimmed.

Grading. Usually five or six size grades are made, the smallest often going to the Pie-grade line and the largest to the slicers. The most nearly perfect

fruit of large size is Fancy grade, next is Choice, Standard, and Second, in that order. As previously mentioned, the fruit below Second in quality is canned as Pie grade. However, these grades depend more upon appearance than upon size. The Pie grade, in addition, comprises blemished fruit, trimmed, overripe fruit, and green fruit. Most canners consider Fancy-grade peaches as those $^{76}/_{32}$ in. or greater in diameter, Choice-grade peaches $^{64}/_{32}$ in. or above, and Standard-grade peaches $^{56}/_{33}$ in. or above, provided

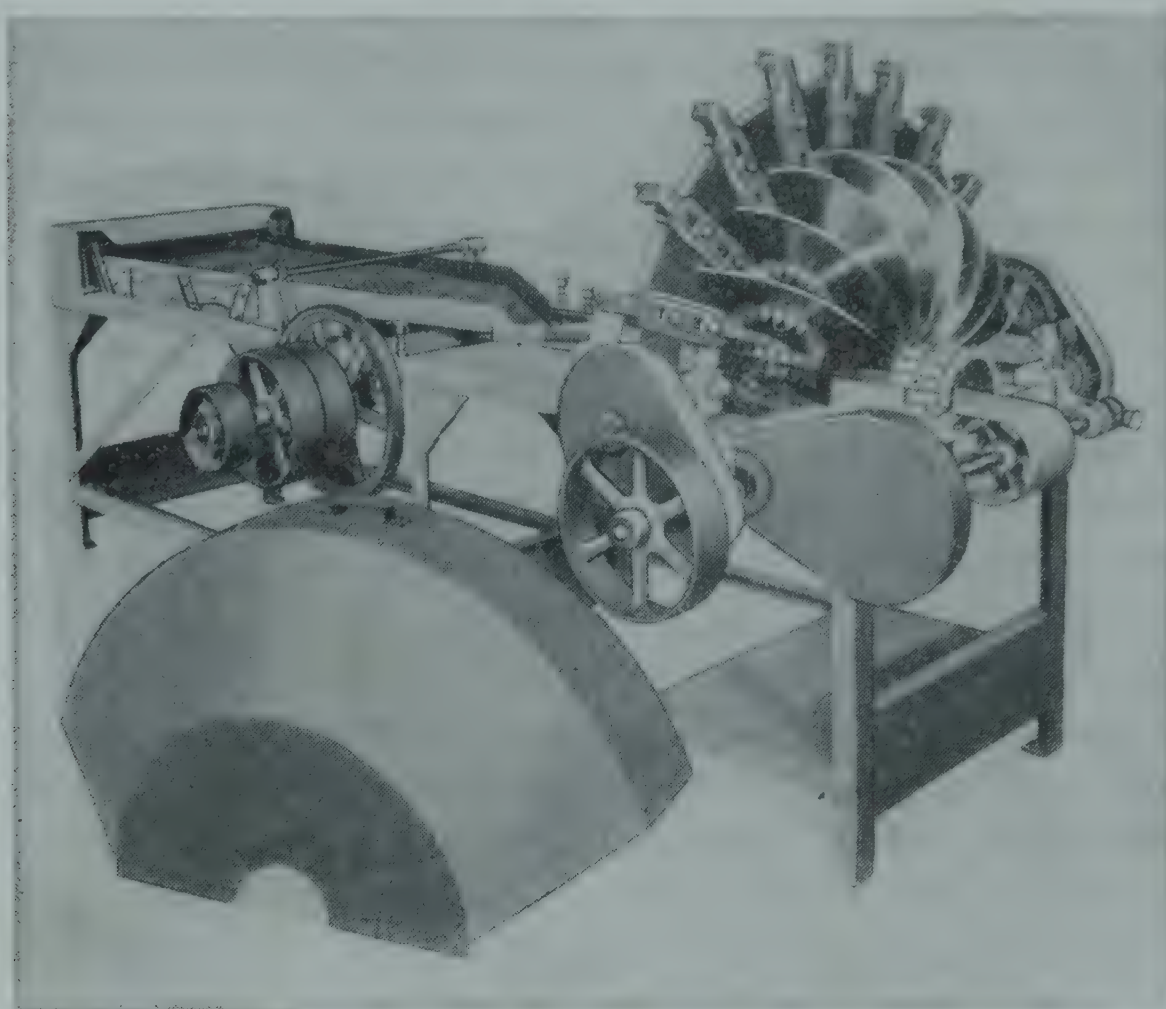


FIG. 36. Peach-slicing machine. (*Food Machinery Corp.*)

the fruit meets the requirements of these grades in other respects. Second and Pie grades are not graded for size (see Figure 16 for appearance of a peach grader). At present much of the Fancy-quality fruit is canned as Choice as there is less demand for the Fancy.

Slicing. There is a good demand for sliced peaches of Choice and Standard qualities; also considerable Pie-grade fruit is sliced in order to make it more attractive and uniform in appearance.

The peach-slicing machine consists of several circular revolving knives against which the halved, peeled peaches are carried by a rubber belt (Figure 36). A vibrating screen automatically places most of the halves cup-side down before slicing. There is a trend toward cutting the halves into fewer slices.

Filling the Cans. From the size-grading machine the halved peaches pass by means of belts to the canning stations. The empty cans are carried to the canning stations by gravity conveyers from a can loft or by conveyers

direct from the can factory or railroad car. The filled cans are usually carried by belt to the siruping machines.

In most canneries the cans are now filled by so-called hand-pack fillers, which are semiautomatic in operation and very greatly reduce the labor cost of canning. The filler consists of a circular revolving stainless-steel table or traveling stainless-steel belt, in both of which are circular holes of the diameter of the cans to be filled. One or two workmen scoop the fruit into the cans through the holes in the table or belt; the cans are automatically fed to the filler, and each can is placed directly beneath a traveling hole. The filled cans are delivered to a conveyer that carries them to the siruping machine. Sliced peaches are also placed in cans by mechanical fillers.

In other canneries the fruit is canned from a slowly moving rubber belt and is sorted for quality as it is being canned. The poorest quality goes over the end of the belt to the Pie-fruit line.

Inspection. The fruit is carefully inspected by the women who fill the cans, and blemished or inferior fruit that has escaped the sorters is segregated and sent to the proper table. Forewomen or inspectors inspect the contents of occasional cans in order to maintain uniformity and care in canning and sorting. In addition, samples are examined in the laboratory; and in plants under continuous Federal inspection many samples are examined by U.S.D.A. inspectors.

Weighing. The cans are sometimes filled by weight by placing the filled can on a small counterpoised scale. The weight of peaches placed in a No. 2½ can will vary from 19 to 22 oz. The government regulations require that a No. 2½ can of peaches contain at least 20 oz. of drained fruit. Great care and considerable skill must be employed in filling the cans in order that they may contain the required amount of fruit without crushing. Some factories fill the cans according to the number of pieces per can rather than by weight, although the weight requirement must also be met. If the semiautomatic filling machine is used, filling is by volume rather than by weight, although net contents by weight must be met.

Darkening. The time that elapses between grading and canning should be as short as possible so that darkening of the fruit through oxidation shall not take place. Oxidation is reduced by keeping the fruit submerged in water if delay occurs and by sprays of water during the grading operations (see also paragraphs on washing and blanching).

Can Sizes. Most of the peaches are placed in Nos. 2½, 2, 303, and 1 Tall cans, with the exception of the Pie grade, which usually is canned in No. 10 cans for the use of bakers, hotels, and other similar establishments. A limited quantity of the higher grades is also canned in No. 10 cans for hotel trade. Sliced peaches are frequently canned in 303 and No. 1 Tall cans and even in 8-oz. cans.

Siruping. The cans are automatically filled with sirup by siruping machines, described in Chapter 5 (Figure 21). The best grade of peaches receives a sirup of 55° Balling and the other grades 40, 25, and 10° Balling and water, respectively, in most California canneries. Some canneries use sirups richer in sugar than those given above, but seldom use sirups more dilute than these. Peaches low in sugar should be given sirups of higher Balling degree than recommended by the Canners' League standards. Fancy peaches should test at least 26° Balling on the cutout test, Choice at least 22° Balling, Standard at least 17° Balling, and Second at least 11° Balling.

As previously stated, sucrose sugar is now bought in the form of a heavy sirup of 67° Brix (liquid sugar), and corn sugar is delivered in a similar manner. Often a blend of the two is used in canning, the blend containing not more than 25 per cent of sugar other than sucrose.

Exhausting. Formerly the filled cans were conveyed from the sirupers through a steam-filled exhaust box for 5 to 6 min. at about 200 to 205°F.

Although some canneries still use the exhaust box, it has been replaced in the canning of fruits to a large extent by prevacuumizing the can contents and sealing the cans in an atmosphere of steam (steam-flow double seaming), as described in Chapter 6 (see Figure 21 for appearance of a vacuumizing siruper for fruits). There is less sirup loss, less floor space is required, and less steam is required than for exhausting in steam. About 4 min. longer processing is required for the cans of fruit sealed cold than is necessary for cans exhausted in steam before sealing.

Marking the Cans. Coding of the cans is extremely important, since it is used to designate variety, grade, and date of packing. It may also give the number of the worker who canned the fruit. The usual method of coding consists in embossing on each lid the letters and numbers of the code by means of metal dies as the lids pass to the double seamer. Some canneries also allow the cans to roll through a device that marks the cans with the number of bands corresponding to the grade, the bands being in indelible ink. Cans so marked can easily be found and recognized and are not apt to be mislabeled. The label covers the bands completely, so that they are not visible to the purchaser.

Sealing. From the exhaust box or the prevacuumizing siruping equipment the filled and siruped cans go to the double-seaming machines to be closed. The machine automatically places caps on the cans and double-seams (seals) them as described in the chapter on tin and glass containers. Modern seaming machines have great capacity; as many as 350 cans of small size, such as baby-food cans, can be sealed per minute, and a rate of 200 or more cans per minute for larger cans is not uncommon.

Since the closure is so very important to the keeping quality of the canned fruit the top double seam of cans taken from the line after double seaming

should be cut and critically examined by experienced operators several times a day so that faulty seaming with subsequent infection and spoilage will not occur. Highly skilled mechanics keep the machine properly adjusted and in perfect operating condition.

If the cans have been exhausted in steam and are hot, no steam is used in the double-seaming operation. If, however, they have been prevacuumized to draw air out of the fruit and sirup and have not been heated in an exhaust box, the double seamer must be equipped for sealing the cans in an atmosphere and jet of steam, as previously outlined. Or a vacuum-sealing machine can be used in place of steam-flow or steam-vac sealing.

Sterilizing or Processing. This is the most important stage in the canning process. It should be thorough enough to cook the fruit sufficiently, but not so prolonged that the fruit is badly softened. The length of sterilization will vary greatly with the maturity and variety. The following table gives the approximate length of sterilization for several varieties of canned peaches. Some canners process No. 10 cans of Pie-grade peaches at 240°F. for about 30 min.

TABLE 16. PROCESSING TIMES FOR PEACHES AT 212°F.

Variety and maturity	Size of can, No.	Approximate time at 212°F. in nonagitating cooker, min.	Approximate time at 212°F. in agitating cooker, min.
Tuscan, prime ripe	2½	20–25	14–20
Midsummer cling	2½	25–30	15–20
Phillips cling	2½	35	25–33
Lovell freestone	2½	20–25	15–18
Solid-pack pie, all varieties	10	40–60	35–45

Cooling. Immediately after sterilization the canned fruit should be thoroughly cooled to a temperature where cooking will cease, but not low enough to prevent drying of the cans. If the can and contents are cooled to a temperature of 110 to 100°F., drying will take place satisfactorily and rusting will not occur. If the cans are not cooled sufficiently, the cooking process will continue in the can, with the result that the peaches become soft and acquire a dark or pink color. One California plant uses a still retort at 226°F. for peaches. Some others use continuous agitating pressure sterilizers for Nos. 2½ and 303 cans at 218 to 220°F. Such a practice shortens the cook and increases the output of canned fruit per day. In one cannery a temperature of 228°F. is sometimes used in the continuous agitating cooker for canned peaches. This temperature is probably near the scorch line for flavor. If the cans have to be sealed cold, the times given in the table must be increased, usually 3 to 5 min.

Cooling is done in a continuous manner in cold flowing water in equipment similar to a continuous agitating sterilizer. If the cooling water is used repeatedly, it should be chlorinated to preclude infection of the can contents with spoilage organisms (see chapter on spoilage).

Storage. Formerly the cans were placed on the warehouse floor in stacks approximately 12 to 20 ft. high, with laths between each two tiers of cans to bind them and to prevent undue strain on the cans at the bottom of the pile. Present practice is to label and case the cans immediately after cooling, or case them unlabeled, and then to store the cased cans in the warehouse.

The warehouse should be cool, dry, and well ventilated, and the cans must be protected against the accumulation of moisture to prevent rusting. In cold climates it may be necessary to heat the warehouse in order to prevent freezing of the cans or the condensation of moisture upon them with resultant rusting.

Cutout Tests. A large number of samples of commercially canned peaches were examined by the National Canners' Inspection Laboratory in southern California (since abandoned). The approximate minimum Brix degrees of the sirups from cans of peaches of the various grades are about as follows: Fancy, 26° Brix; Choice, 20; Standard, 15; Second, 12; and Water or Pie, 9. Usually, in commercial practice, the Brix degrees are somewhat above the minimum.

The results indicated that the ruling of the U.S.D.A. that No. 2½ cans of peaches contain 20 oz. drained weight of fruit is rather a severe condition to meet in commercial practice for Fancy and Choice grades. For more recent data on cutout tests for various fruits see Chapter 4. The cutout test varies considerably with the variety of peaches, their maturity, the ratio of fruit to sirup, and the locality and season.

During the day many samples are cut and examined in the cannery laboratory. Among other observations the texture, drained weight, workmanship, density of sirup, grading, color, flavor, blemishes, and general quality of the samples are determined. See also Chapter 4, the section on quality control.

Pie Fruit. The trimmed, overripe, and otherwise low-quality fruit is canned as Pie fruit. Much of it is sliced before canning. It is heated in live steam for about 8 to 10 min., canned scalding hot in No. 10 cans, and sealed hot. If it is sealed at 195°F. or above, some canners find that additional processing is not necessary, if the hot cans are allowed to stand several minutes before they are cooled. Paneling of the cans handled in this manner is apt to be quite severe. Some canners prefer to give the sealed cans a process in an agitating continuous cooker for 30 to 40 min. to preclude any danger of spoilage. The cooling water in either case should be as nearly sterile as possible, as during the initial stages of cooling a drop or two of the cooling water may be drawn into the can before the sealing compound has

hardened. So-called "break-point" chlorination of the water will render it nearly sterile and very much less apt to contaminate the contents of the cans during cooling.

Yields and Waste. Commercial canners have reported yields of canned cling peaches of 45 to 50 cases per ton. In extensive canning tests with commercial-scale equipment, Leonard et al. of the Food Technology Department of the University of California found the average loss in pitting with a knife-type mechanical pitter was 13.45 per cent and by torque pitter 10.44 per cent. The average loss by knife-type mechanical pitter and immersion lye peeling was 24.30 per cent; by torque pitter and cup-down spray lye peeler, only 15.94 per cent. The increased yield of peeled and pitted fruit was about 160 lb., or about five cases in these experiments, per ton of fresh peaches.

The pits are sent to the dump or are spread in the sun to dry to be used for fuel or sold locally to cannery workers or others for fuel purposes. Some are also used for charcoal production for making briquettes. During the First World War large quantities of the pits were cracked and the shells were used for the preparation of a carbon of high absorptive power for use in gas masks. Chemicals were used for this purpose in the Second World War. The kernels, which comprise about 15 per cent of the weight of the pits, can be recovered and used for the preparation of sweet oil and bitter-almond oil, but the cost of recovery is so high that the products cannot economically compete with those from apricot kernels. The whole pits have been dry-distilled to produce acetic acid, acetone, and charcoal, the last being used in poultry foods.

The waste lye solution containing the peels and the waste wash water is of no economic value, and its disposal in some localities has presented a serious problem because the sodium hydroxide renders the soil alkaline and toxic to plants. Further discussion of the utilization of peach and other fruit and vegetable wastes will be found in Chapter 23.

Labeling and Packing. Canned peaches and other canned fruits and vegetables in cylindrical cans are labeled by portable automatic machines. The cans are placed in a runway above the machine by a workman or may be delivered by conveyer directly from the can cooler and pass by gravity through the machine. The cans first pass over small rollers that apply the label paste, which may be glue, a casein preparation, dextrin mucilage, or other adhesive. They next roll across a stack of labels, one of which is picked up by the label paste on the can and is smoothed in place automatically by the machine. Adhesive is applied automatically to the end of the label, and the label end is sealed to the can. See Figure 7 on page 30.

Boxes. The labeled cans are packed at once into cases, 24 cans of No. 2½ and 48 of small-size cans per case, or 6 No. 10 cans per case. Wooden cases were formerly most commonly used, but fiberboard (heavy paste-

board) and corrugated fiberboard boxes have been adopted by most canners. Wooden cases are advisable for export.

APRICOTS
(Prunus armeniaca)

The apricot is second in importance to the peach among California canned fruits. The average pack of canned apricots is about 5 million cases, which represent about 100,000 tons of fresh fruit. The pack in 1956 was 5,085,000 cases, and in 1955, 3,412,000 cases, according to *Western Canner and Packer*. This quantity is slightly less than the normal tonnage of fresh apricots dried in California. At an average price of 20 cents a pound for the dried fruit and a yield of 400 lb. of dry fruit per ton of fresh, a ton of fresh apricots will yield a gross revenue of about \$80, whereas a ton of the fruit after canning will yield approximately \$220 at \$2 per dozen No. 2½ cans. Canning is much more costly than drying. In most cases the overripe fruit is dried, and the prime ripe fruit is sent to the cannery or fresh market. Fruit that is smaller than 14 to the pound is used chiefly for canning whole or for production of nectar. See Chapter 12 for canning of nectar.

Varieties. The Blenheim apricot is the most popular variety for canning purposes. It is of moderate size, of deep-yellow color, of excellent flavor, and reasonably free from scab or blemishes. When properly ripened, it has uniform texture from the skin to the pit and retains its shape in the can during processing. It is grown most extensively in the counties bordering the San Francisco Bay region in California.

The Royal apricot is grown in southern California and in the hot interior valleys. It is somewhat smaller in size than the Blenheim and of a more intense orange color. However, it is claimed by many nurserymen that the Royal and the Blenheim are identical and that the differences in appearance noted in commercial culture are due entirely to the effect of locality and to climatic conditions. The Royal apricot grown in hot, dry sections often becomes soft near the pit, a condition that renders it more or less unsuitable for canning purposes.

The Moorpark is a very large variety, grown in limited amounts in central California. This variety does not bear so heavily or so uniformly as the other two varieties and tends to ripen unevenly. Its large size and excellent quality make it very much in demand for sale in the fresh-fruit markets.

The Tilton is a very important variety grown in the hot interior valleys of California, in eastern Washington, and in British Columbia. It is of large size but is rather pale yellow in color. It is considered inferior to the Blenheim for canning.

Harvesting. The fruit on the tree is at its optimum degree of maturity

for canning purposes for 1 or 2 days only. If it is too green the canned fruit will have a disagreeable astringent flavor, and no amount of sugar will entirely overcome this defect. If it is overripe, it will be too soft and will be unattractive in appearance after sterilization. When gathered at the "canning-ripe" stage of maturity, the fruit is firm, of full size, of good color, and of pleasing flavor. It will not have reached the maximum flavor, however, at this stage of ripeness. There is now a tendency to can some apricots soft-ripe in the whole condition. This is an excellent product in respect to flavor although rather jamlike in appearance, unless very carefully handled and not overcooked.

The canner desires that the finished product shall retain its clear-cut appearance and that the sirup shall remain clear and reasonably free from pieces of broken fruit. At the same time it is necessary that the fruit have a reasonable amount of flavor. To obtain these results, the apricots should be transported to the cannery as rapidly as possible after gathering and should, if possible, be canned on the same day they are picked, as they cannot successfully be shipped long distances. The trucks used in transporting them should be equipped with good springs to prevent bruising of the fruit in transit.

Apricots are subject to brown rot, *Sclerotinia fructigena*, a fungus that attacks the flowers and green shoots during the spring and the ripe fruit in foggy or rainy weather. It sometimes attacks the fruit in the lug boxes. They are also subject to scab, another fungus disease. Both diseases can be controlled by spraying the trees with Bordeaux spray at the proper times.

Receiving. Most canners examine each delivery of apricots to determine roughly the percentage of the different grades, and payment is made to the grower on the basis of this "door test." For example, in a typical test 25 lb. of a mixed sample was taken for a grading. Three grades were made and designated as grades A, B, and C. There was found to be 17 per cent of A, 72 per cent of B, and 11 per cent of C grade, for which the grower was paid at the rate of \$60, \$25, and \$12, respectively.

Many canners make only two grades, viz., apricots counting 12 or less to the pound and those counting 12 to 14 to the pound, paying much less for the smaller fruit. However, much of the fruit of smaller sizes is now used for canning whole and for production of nectar.

Pitting. The apricots are halved and pitted but are generally not peeled. The fruit is cut by hand around the pit suture, and the pits removed; or now more commonly the fruit is cut by a small machine fed by hand. A small proportion of the crop, however, is lye-peeled in the same manner as described for peaches, although the lye used is weaker than that used for peaches. The grading of the halved and pitted fruit is carried out in the same manner as described for peaches (for size grades see Chapter 4). Much of this fruit is now canned unpitted.

Slicing. Some of the largest fruit is sliced and canned for a special trade.

Grading. Screens with openings $^{40}/_{32}$, $^{48}/_{32}$, $^{56}/_{32}$, $^{64}/_{32}$, and $^{68}/_{32}$ in. are used for apricots. The average diameters of Fancy, Choice, and Standard grades are usually $^{56}/_{32}$, $^{54}/_{32}$, and $^{50}/_{32}$ in., respectively however, these grades are based more upon color, texture, ripeness, absence of defects, etc., than upon size.

Canning. The graded fruit is conveyed to the canning stations in the manner described for peaches. It is usually canned by hand-pack filler. In some canneries the fruit is canned from a broad, slowly moving belt.

Siruping. The filled cans are siruped in the automatic siruping machines with sirups of the concentrations recommended by the California Canners' League of 55, 40, 25, 10° Balling and plain water, according to whether the grade is Fancy, Choice, Standard, Second, or Pie. Some canners use sirups 5° Balling richer in sugar than those given above or sirups of such density that the cutout Brix degree after canning will equal or exceed Canners' League minimum requirements.

Owing to its high acidity as usually delivered for canning, the apricot is not pleasing in flavor as a dessert fruit unless it is canned in a heavy sirup, 40 to 55° Balling. There is, however, a good demand for it in lighter sirups and in water for the making of pies.

Yields. The average yield of halved canned apricots per ton is about 55 cases of 24 No. 2½ cans. The loss in canning of the unpeeled halved fruit is about 9 to 15 per cent. Where the fruit is peeled, the loss will exceed 30 per cent, based on the weight of the fresh fruit. The yields of whole canned apricots will usually exceed 70 cases per ton.

Apricot pits are in demand for the manufacture of by-products such as both sweet and bitter "almond oil" and macaroon paste. They are usually dried by spreading in the sun, to a depth of about 1 ft., on a cement floor or on rolled ground, stirred daily until dry, and then placed in sacks to be shipped to by-products plants. Apricot-pit by-products are described in Chapter 23.

Exhausting. Apricots are exhausted as described for peaches.

Common practice consists in prevacuumizing the canned product and closing the cans in an atmosphere of steam as described for the canning of peaches.

Sterilizing or Processing. After exhausting and sealing, the cans are immediately sterilized, usually in continuous agitating cookers. The time of sterilization of halves in No. 2½ cans at 212°F. varies from 8 to 18 min., depending upon the locality and upon the variety and maturity of the fruit. The usual process is 10 to 15 min. Too prolonged sterilization will soften the fruit badly. Very little softening of the apricots by cooking is required, and for this reason the cans should be thoroughly and quickly cooled after sterilization. Some canners process the canned fruit, both halves and whole, at 220 to 214°F. for 14 min. in a continuous agitating pressure sterilizer.

Canned Pulp and Pie Fruit. Some fruit, particularly that which is overripe, is pulped in tomato pulpers and canned for use in ice cream, etc. In most canneries the Pie-grade fruit is steamed thoroughly to soften it and is packed as solid-pack fruit without the addition of water or sirup. It requires heavy sterilization because of slow heat penetration, e.g., 45 min. at 230°F. or 45 to 60 min. at 212°F. in an agitating cooker. If canned boiling hot, a shorter process can be used; but paneling of large cans may then occur, unless the cans are of reinforced type.

Whole Fruit. Much fruit is now canned whole, some of it lye-peeled. Ripe fruit is graded for size, sorted, and canned without peeling or is lye-peeled and canned. The whole fruit requires a longer period of processing than the halved, viz., 18 to 25 min., depending on size of the can and maturity. The present procedure for canning whole apricots is about as follows: They are dumped from the lug box into water, elevated to a spray washer, and then sorted and canned from a long, wide, slowly moving belt. Fancy and Choice grades and larger sizes are removed first and canned at the front end of the belt, and the green and other low-grade fruit passes over the end of the belt for pitting and canning as Pie fruit.

Pitted Whole Apricots. Considerable Pie-grade fruit is now pitted mechanically by Elliott pitters, then steamed and canned as solid-pack Pie fruit, giving a superior product for this purpose. If it is canned boiling hot, additional processing is usually not necessary.

Cutout Tests. As in the canning of all fruits, frequent tests are made of the quality of the canned apricots and the Brix degree of the sirup. The minimum concentrations of the sirups from the various grades of canned apricots should be, according to data given by commercial canners, Fancy, 27° Brix; Choice, 21°; Standard, 17°; Second, 12°; and Pie grade, 9° Brix. It will be found that the net weight of drained fruit is somewhat lower than for peaches, because of the greater tendency of apricots to soften and shrink during sterilization.

Vacuum Sealing of Cans. Some canneries now seal the cans under high vacuum without previously heat exhausting. With apricots this gives a superior product. It also avoids sirup loss and saves floor space and steam. The same is true of prevacuumizing followed by steam-flow closing. However, cans that are sealed cold require several minutes longer processing than those sealed hot.

APPLES
(Pyrus malus)

The apple is canned extensively in the Pacific Northwest and in the Eastern states, particularly in New York and Pennsylvania. It is used principally for the preparation of pies and sauce in restaurants, hotels,

cafeterias, etc. Housewives prefer to use the fresh product or the dehydrated article.

The canning of apples is considered a by-product industry in most apple-growing districts and as a means of utilizing the best quality of culls. The fruit for canning purposes should be of fair size and reasonably free from blemishes. Apples unfit for canning may often be used for cider or vinegar. The two principal forms are quarters or segments in water and canned applesauce.

Varieties. Apples for canning should be firm and hold their shape in the can. They should be of good flavor, color, and texture. Acid varieties of white flesh are preferred.

On the Pacific Coast the Yellow Newtown Pippin, Winesap, Jonathan, and Spitzenberg are popular for canning purposes. Other firm apples of white flesh and of pronounced apple flavor that can be obtained in commercial quantity can be used successfully. The following have also been used: Northern Spy, Stayman Winesap, Wagener, Roxbury Russet, and Rome Beauty. Mealy varieties, or those that become "applesauce" during processing or take on a pink or yellow color when cooked, are not so desirable for canning.

Peeling and Coring. The fruit should be washed and sorted before it goes to the preparation tables. It is peeled by mechanical peelers, operated by power; the apples are placed on the peeling knives of the machine by hand. The peeled and cored fruit is trimmed by women who work at another belt to which the fruit is delivered by conveyer; those who do the trimming also cut the fruit into quarters or smaller segments. Ordinarily the fruit is put immediately in dilute brine to prevent oxidation and browning. The peels and cores, which normally represent from 30 to 40 per cent of the weight of the fresh fruit, are usually sent to the vinegar factory to be crushed and pressed for vinegar, although some factories have found it profitable to dehydrate the peels and cores for the use of jelly and pectin manufacturers, from whom there was a good demand formerly.

Blanching. Before the apples are canned they are usually blanched in one of several ways. A simple process of blanching consists in passing the quartered or sectioned apples through a steam box to soften them, to destroy the oxidase, and to expel the air from the fruit, thereby reducing pinholing of the tin plate.

In some canneries the fruit is immersed in boiling 3 per cent brine for 3 or 4 min. to accomplish the results mentioned above.

It is possible to remove the air by placing the fruit in dilute brine or water and subjecting it to a high vacuum. The air is effectively removed, and water enters the fruit tissues to replace the expelled air, increasing the weight of the fruit considerably. Another method in fairly common use consists in heating the fruit several hours in water at 120°F. or lower temperature. E. F. Kohman found that this treatment removes oxygen

from the tissues by respiration. The fruit is also blanched before canning.

Canning. Following the blanching operation, the hot fruit is packed at once into No. 2½ or 10 cans as a solid pack, or a small amount of boiling hot water is added. In most cases, however, the can is practically filled in solid-pack style, and very little liquid is necessary. Type L or similar corrosion-resistant cans should be used.

Exhausting. More trouble has been experienced by the corrosion and pinholing of tin plate by apples than by other canned fruit. It has been proved by Bigelow and other investigators that the corrosion is caused by the malic acid of the apples in the presence of air or oxygen and that corrosion is limited or reduced to a negligible degree if the air is thoroughly expelled from the fruit by blanching and from the can and contents by thorough exhausting.

Sterilizing. Apples are easily sterilized on account of their high acidity, but because the fruit is packed tightly in the cans, heat penetration is not very rapid. Nevertheless, a sterilization of 8 to 10 min. at 212°F. in a continuous agitating sterilizer has been considered sufficient if the cans have been filled and sealed above 160°F.

Pinholing of Tin Plate by Apples. As noted above, a serious problem in the canning of apples is the frequency of corrosion of the tin plate. As proved by Bigelow, Huenick, Wiegand, Todd, and others, blanching and thorough exhausting are effective means of minimizing corrosion. Huenick, of the American Can Company, recommended the use of a heavy tin plate, Char A-1, and found that this is more desirable than lacquered tin plate, for the reason that the latter often has small areas that are not perfectly covered with the lacquer. Modern Type L or similar cold-rolled plate is now advised, as it is very resistant to corrosion. This plate has been developed since the work of Huenick.

Corrosion is favored if the cans are allowed to remain hot for several hours after sterilizing. It has been found desirable to invert cans of ordinary tin plate in the warehouse 3 days after canning and again at regular intervals during storage, because corrosion takes place most rapidly at the water line in the can and, if the can is inverted frequently, corrosion is distributed over a greater surface (Chapter 11). Cans made of Type L plate have eliminated much of this trouble.

Applesauce. The canning of applesauce is described at the end of this chapter. See also the canning of fruits for use in pies in the home on page 195.

BLACKBERRIES
(*Rubus villosus*)

Moderate quantities of blackberries are canned in the Pacific Northwest for use in the preparation of pies. Freezing is supplanting canning.

Varieties. In Oregon and Washington, the Evergreen variety, which is an improved strain of the wild blackberry, is most popular.

In California the principal variety is the Boysen blackberry, which is a hybrid and similar in composition and flavor to the loganberry. It is very large, of good color, and of high acidity.

The Lawton blackberry ripens later than the Boysen blackberry and is smaller and sweeter. It is excellent for jams and preserves and is more in demand for this purpose than for canning. The Himalaya blackberry, a small berry of good color and flavor, ripens in August, September, and October and is canned in small quantities, but because it ripens late in the summer, it is more in demand for the fresh market than for canning. Any good table variety may be used for canning. Very few berries are canned in California; none in 1955 so far as can be ascertained.

Harvesting. Blackberries should be harvested in shallow boxes and should be picked frequently, daily if possible, so that the fruit may be at the optimum stage of maturity. It is desirable that the fruit be canned on the same day that it is picked, otherwise serious deterioration will take place, even with the greatest care in transportation and storage.

Canning. At the cannery the fruit is generally merely sorted and very thoroughly washed, very little attempt being made to grade for size. Since most of the fruit is used for pie making rather than for dessert purposes, it is generally packed in water or in light sirups. Fruit for dessert purposes should be packed in sirup of 40 to 55° Balling. In one large Oregon cannery in 1955, the berries were dumped from small baskets into water, elevated to a sorting belt, given a preliminary sorting, graded by machine into five size grades, again sorted from slowly moving belts, and then canned. The smallest berries are canned in No. 10 cans in water for use in pie bakeries. The larger berries are canned in sirup in 303 size cans for use as dessert in the home. The cans are thoroughly exhausted in steam and closed and processed at 212°F. for 11 to 14 min.; longer for No. 10 cans.

In plain tin cans the color of the sirup and of the fruit bleaches rapidly. Therefore it is customary to can the berries in enamel-lined (lacquered) cans. The preferred can is one made of Type L plate and coated inside with two coats of so-called "berry enamel."

The fruit may also be canned as a light preserve after boiling 3 to 4 min. with an equal weight of sugar. In this case no sirup, except that formed in cooking, is added.

LOGANBERRIES

Oregon is a fairly large producer of loganberries, which are used for canning, frozen pack, jams, and juice. The berries are very large in size and deep red in color.

The canned fruit is most in demand for pie-making purposes and therefore is canned in No. 10 enamel-lined cans. The processes of harvesting, canning, and sterilizing are practically the same as for blackberries. "Double-enameled" Type L cans should be used to ensure the retention of color. The berries are usually canned in No. 10 cans in water.

RASPBERRIES
(Rubus strigosus)

Raspberries are grown throughout the United States and canned in small commercial quantity in the Northern and Middle Western states, in New York, and on the Pacific Coast. They are of greater importance in Great Britain for canning, but are popular in America for freezing and for jams. The red raspberry is preferred to the black variety for canning purposes but is more in demand for the preparation of preserves and jams than for canning. The berries are canned in lacquered cans, preferably of Type L plate, in heavy sirup for dessert purposes and in water for use in pies. The length of sterilization is usually about 12 min. at 212°F. They may also be canned after cooking a short time with half their weight of sugar. They are usually frozen rather than canned.

STRAWBERRIES
(Fragaria virginiana)

Strawberries for canning purposes should be firm in texture, of good color and flavor, and of large size. The Marshall and Ettersberg are used in the Pacific Northwest. In California the Shasta and Lassen are the principal varieties at present, but are used for freezing. The most important requirement is firm texture. The principal difficulty in the canning of strawberries is the softening of the fruit during sterilization, which results in the can containing only one-third to one-half its volume of berries. Strawberries are used for preserves and for frozen pack in very much larger quantities than for canning.

Strawberries shrivel if canned in too heavy a sirup, although a fairly heavy sirup is necessary to develop and retain the berry flavor. A sirup of 50° Balling is satisfactory. Strawberries are much more satisfactory for preserving and for frozen pack than for canning.

CRANBERRIES

Cranberries are now canned commercially in Massachusetts, the Pacific Northwest, and other cranberry-growing areas. They are grown on land

that can be flooded during the growing season, i.e., in cranberry bogs. They ripen in the fall and are picked by hand with a special rakelike device or by a machine that makes use of powerful air suction to strip the berries from the vines and convey them to a cleaner and hopper. At the cannery the berries are cleaned by screening and winnowing to remove leaves, trash, etc.

For a sauce containing the whole berries, sugar and the requisite amount of water are added. The mixture is then boiled until it reaches the jellying point, which is judged by the usual jelly-sheeting test or by boiling point. It is canned scalding hot into heavily enameled, corrosion-resistant cans, and the cans sealed and cooled to about 100°F.

The strained sauce is made by boiling the berries with the requisite amount of water to soften the fruit and release the pectin. They are then put through a pulping machine, similar to a tomato pulper, with fine screen for a sauce free of seeds, or a coarse screen, if a sauce containing a few seeds and rather coarse particles of pulp is desired. Sugar is then added, and the mixture boiled to the jellying point and canned as above.

Stainless steel or monel metal or other corrosion-resistant metal must be used because of the high acidity and intense red color of cranberries. The annual pack for the United States is about 3 million cases. The 300 and No. 2 sizes of cans are popular for home use, and the No. 10 for institutional use.

BLUEBERRIES

According to Darrow et al. (1944) *U.S. Department of Agriculture Farmers' Bulletin*, 1951, blueberries are grown from Florida to New Brunswick in the Atlantic coastal states, in Michigan, Wisconsin and Minnesota, and in the three Pacific Coast states. They require an acid soil and do best in one high in organic matter. Most varieties require soils high in moisture, but also one that is well drained. A water table at 18 in. is considered optimum, according to Darrow et al.

In Maine, New Brunswick, and in upper Michigan the low-bush varieties grow wild in extensive areas. The vines grow to only 4 to 10 in. high and form a mat, or sod. They are usually burned over once in 3 years to kill and discourage weeds and encourage increase in number of vines. The berries are small and usually picked with small scooplike rakes.

The high-bush varieties are grown under cultivation in New Jersey, Maryland, southern Michigan, and elsewhere. They are principally selections of large-size berries developed by Coville. The vines attain 3 to 10 ft. in height, and the berries are much larger than those of the wild low-bush varieties. A third type, the so-called Rabbit Eye Blueberry, is found wild and is grown quite extensively under cultivation in Florida, Georgia, and

elsewhere in the South. The berries are larger than the low-bush berries. The high-bush blueberries and Rabbit Eye Blueberry are hand-picked and on that account require less cleaning than the low-bush berries picked by raking. The Rabbit Eye berry bushes grow even taller than the high-bush variety.

The low-bush berries are cleaned mechanically in the fields by a winnowing machine that removes leaves, small twigs, and other light trash by air blast. At the cannery all types of blueberries are washed and then sorted carefully from a slowly moving belt.[1] They may then be canned in water in No. 10 cans for the pie-baking trade, or in sirup for the retail trade or for home use as a dessert fruit. According to Bedford, commercial canning is conducted about as follows.[2] The cans are exhausted in steam, as described for other fruits, and sealed hot. The No. 2 cans are processed 12 to 16 min., and No. 10 cans 25 to 30 min. at the boiling point. Some berries, particularly in Maine, are kettle-cooked and canned hot in No. 10 cans. Ruyle, Pearce, and Hays have reported (1946) on spoilage of kettle-cooked canned berries by a heat-resistant mold. A short process at 212°F. of the canned product is advisable in such cases. For further information on blueberry canning see Isker and Maclinn Campbell's book, 1950, listed in references at the end of the chapter.

Blueberries are subject to several diseases and insect pests, the most serious being a fly that emerges from its winter pupal stage in early summer and lays eggs inside the berries. These hatch into small worms that render affected berries unsalable. It is reported that the infested berries can be removed by flotation or by gentle rubbing on a screen. The fly is controlled by DDT very effectively.

The 1954 Census reports the following data on blueberries:

	Acres
Maine	26,500 (mostly low-bush, wild)
New Jersey	4,879
Michigan	4,167
Massachusetts	2,295
New Hampshire	1,645

The high-bush is grown in New Jersey, and both the high- and low-bush types are grown in Maine and Michigan. In the South the Rabbit Eye blueberries are grown. Darrow et al. states that in 1944 Florida had over 2,000 acres of this variety.

In California the evergreen type, usually called huckleberry, grows wild and is gathered and sold fresh for pie making. In Oregon and Washington

[1] The author is indebted to Professors M. E. Highlands, C. L. Bedford, and W. A. Maclinn for much of the information presented on blueberries.

[2] Personal communication.

the cultivated as well as the wild blueberries are grown, and also the evergreen grows wild, as in California.

Highlands has developed satisfactory formulas for the canning of blueberry-pie filling in No. 2 cans for home use or larger cans for bakery use (see reference list).

CHERRIES

(Prunus cerasus)

The principal districts in which cherries are grown for canning purposes are New York, Michigan, Oregon, and California. In the Eastern states the sour varieties are most commonly used, whereas on the Pacific Coast a sweet cherry, the Royal Anne, is the principal variety used for canning. This is a large, sweet variety of white or light pink color.

Preparation. After its arrival at the cannery in most plants, the fruit is first stemmed by hand or by mechanical stemmers. One stemming machine consists of a slightly inclined cylinder about 4 ft. long and about 2 ft. in diameter, which rotates at about 20 to 30 r.p.m. The cylinder is made up of a series of short rubber rollers about 3 ft. long and about 1 in. in diameter. As the cylinder rotates, the rollers are enmeshed at one end by a cogwheel when the rollers are at the lower position during rotation. As the rollers turn, they catch and pull through stems and leaves, leaving the cherries uninjured on the inside of the cylinder. The cherries are fed in at the upper end of the cylinder and emerge at the lower end with 95 per cent or more of stems removed. In another stemming machine the stemming rolls lie in a plane, but operate as outlined above. Following the stemming, the fruit is thoroughly washed.

It then goes to the same machine used for the grading of peaches and apricots, except that screens with holes of smaller diameter are used. The usual sizes of screen used in the grading of cherries are $^{20}\!/_{32}$, $^{22}\!/_{32}$, $^{23}\!/_{32}$, $^{26}\!/_{32}$, $^{28}\!/_{32}$, and $^{33}\!/_{32}$ in.

With good-quality fruit these screens yield the grades established by the Canners' League of California.

Pitting. Most of the sweet cherries are canned without pitting, although most sour cherries are pitted. The pitting is accomplished by an automatic machine in which cherries fall into small cups and in which the seeds are removed by cross-shaped plungers. The loss in pitting is about 15 per cent of the weight of the stemmed cherry. Considerable juice is expressed from the cherries in pitting and may be recovered for canning as juice or for use in sirups. See Figure 37.

Sirups. The highest grade of cherries receives a sirup of 40° Balling. Sirups of greater density than this cause the fruit to shrivel. The other grades receive in California 30, 20, and 10° sirups and water, respectively.

Exhausting. Cherries should receive a long exhaust, at least 10 min. at a moderate temperature, at 165 to 185°F., in order to eliminate air and to prevent pinholing. In practice, however, a shorter exhaust at a higher temperature is used, although it is admittedly less desirable. This is particularly true for sour cherries, which corrode tin plate rapidly. Type L or

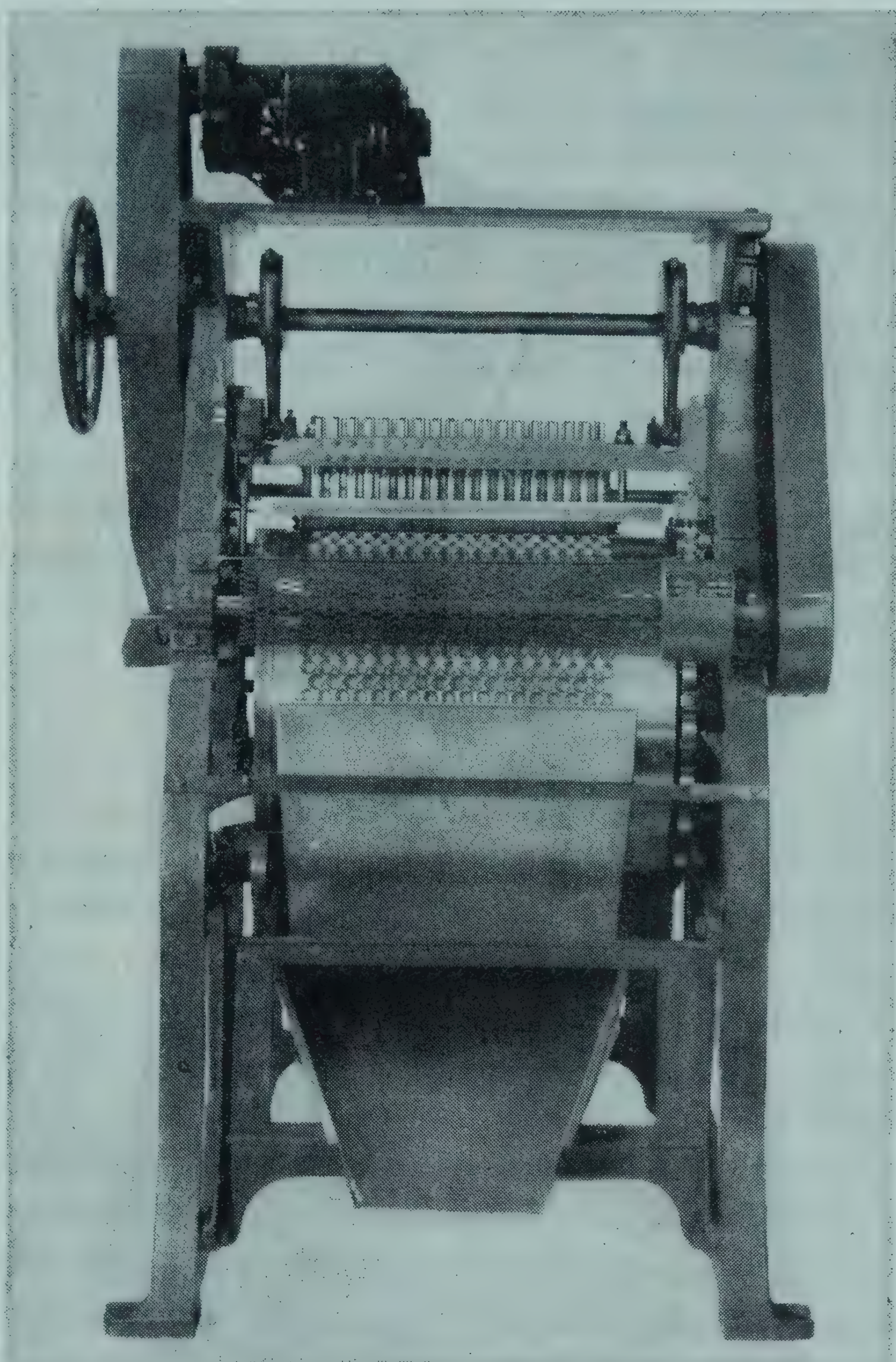


FIG. 37. Dunkley cherry pitter. (*Food Machinery Corp.*)

similar plate should be used. Prevacuumizing of the canned product followed by vacuum or steam-flow closing can also be used. G. H. Bohart of the National Canners Association recommends a large head space in which the hydrogen formed by corrosion during storage may collect and thus prolong the life of the canned product. The use of Type L cans has largely eliminated the corrosion problem for cherries.

Sterilizing. The length of sterilization is from 12 to 25 min. at 212°F., depending upon the variety and maturity of the cherries and size of the can.

GRAPES
(Vitis vinifera)

The principal grape canned in commercial quantities is the Muscat of Alexandria, the highly flavored sweet European variety of raisin grape grown in California.

The bunches possessing the largest berries are selected for canning purposes. At the cannery the fruit is removed from the stems by hand and defective berries are removed and discarded. It is then taken immediately to the graders fitted with $^{20}\!/_{32}$-, $^{21}\!/_{32}$-, $^{24}\!/_{32}$-, and $^{26}\!/_{32}$-in. openings. The graded fruit is washed and packed into No. $2\frac{1}{2}$ or 10 cans. The cans are filled with sirups of 40, 30, 20, and 10° Balling and water, respectively, for the five grades. After exhausting and sealing, the fruit is sterilized for 12 min. at 212°F.

Thompson seedless grapes are added to fruit cocktail at the time of canning. Small quantities also are canned in water or in light sirup for use in pies as a substitute for gooseberries.

PEARS
(Pyrus communis)

On the Pacific Coast the Bartlett pear is the variety most commonly used for canning. In the Eastern United States the Kieffer is used, because the Bartlett is not grown extensively on account of its susceptibility to blight. The Bartlett pear is desirable because of its uniform shape, its white color, and its relatively small number of grit cells. The Kieffer pear is smaller than the Bartlett and of less desirable color and texture. The Hardy variety is sometimes used in fruit cocktail in California.

Harvesting and Ripening. Pears develop a better flavor and are of finer-grained texture if ripened in boxes after picking. Fruit ripened on the tree is apt to be coarse in texture. The pears are gathered at full size, while they are still hard and green, and are shipped in this condition direct to the cannery where they are held for from 5 to 10 days to ripen. Allen of the University of California and Magness and Diehl of the U.S.D.A. recommend that pears be picked according to pressure tests made with the Magness pressure tester. The test is made by noting the pressure required to force a $\frac{5}{16}$-in. plunger $\frac{5}{16}$ in. into the flesh of the pear with skin removed. They recommend that for optimum results the test should be about 17 to 19 lb. and that pears showing a pressure test above 23 lb. should not be used. Color is also a good index of maturity; the color between the lenticels should be a lighter green than the lenticels (for details of the test see Magness, Diehl, and Allen).

After picking, the pears are brought to the cannery in 50-lb. lug boxes for ripening. They are graded for size by roller or diverging belt-type grader. They are then allowed to ripen in lug boxes in a large room in which the temperature is controlled, usually between 68 and 75°F. Formerly sorting was done during ripening, but at present this may be omitted since ripening is usually quite uniform under controlled temperature and humidity.

Chace and Sorber report experiments in which the ripening of Bartlett pears was successfully hastened by subjecting them to ethylene vapors in the manner commonly used for coloring oranges. The use of ethylene in hastening the coloring and ripening of fruits was discovered by Denny, formerly of Dr. Chace's laboratory of the U.S.D.A., and is covered by U.S. Public Service Patent 1,475,938, granted in 1923. As applied to pears, the lug boxes of fruit were placed in tight rooms or under canvas and exposed intermittently to concentrations of ethylene of 1:1,000 to 1:5,000 in air. Once each 24 hr. the ripening rooms were opened and ventilated for 1 hr., preferably by fan, to remove the products of respiration and to promote uniform ripening. In a typical test the treated pears ripened uniformly and satisfactorily in 4 days, whereas the untreated pears required 7 to 8 days for ripening and ripened less uniformly. Where ripening is satisfactory and uniform without ethylene treatment, Chace and Sorber state that its use is of no great benefit. On the other hand, where several sortings are necessary because of nonuniform ripening, the use of ethylene is profitable and desirable. Ethylene not only hastens coloring and ripening but also increases the rate of respiration, as evidenced by carbon dioxide evolution.

During ripening the starch of the fruit is converted to sugar, a change that is easily followed by applying dilute iodine solution to the cut surface.

Pears that are too immature when picked do not ripen properly but become somewhat shriveled, and the flesh after canning is apt to be yellow in color and stringy in texture. Those which are picked too mature are apt to be grainy in texture and may become excessively soft around the core before they are fully ripened near the surface.

Quality in canned pears depends to the greatest degree upon picking at optimum maturity, ripening at proper temperature, sorting carefully, and selecting the fruit for canning at optimum texture (ripeness). In most canneries the ripening is followed by the Ballauf pressure tester, which is similar to the Magness tester. Leonard et al. recommend that pears to be canned as halves be ripened to 2 to 3 lb. Ballauf test. If for use in fruit cocktail, they are ripened to a firmer condition.

Frequently it becomes necessary to store some of the pears for 2 or 3 weeks before ripening and canning. A temperature of about 32 to 33°F. should be used, and the lug boxes of fruit should be so stacked that free circulation of air between the boxes is secured. If the boxes are stacked too closely together, the gaseous products of respiration accumulate in the

boxes and cause scalding (browning of the skin) and development of off flavors.

Preparation. The fruit may be peeled, halved, and cored by hand, a special guarded knife being used for peeling. The direction of peeling is from the stem toward the calyx, not around the pear. The core, stem, and calyx are removed by a loop-shaped knife. At the same time, the fruit is graded by hand according to size, usually five grades being made in accordance with the standards of the Canners' League of California, as given in Chapter 4. The Fancy grade represents 8 to 10 pieces, the Choice 10 to 12, and the Standard 12 to 17 pieces per No. 2½ can. In recent years mechanical graders of the diverging cable or roller types have come into use for grading the pears for size before ripening. Fruit to be peeled by the Ewald peeler must first be graded for size.

Pears oxidize and turn brown very rapidly after peeling, and if they are to be held for more than a few minutes, they should be placed in dilute brine, 1 to 2 per cent salt, or in water. Brine checks the action of oxidase, the enzyme responsible for browning.

Pears have been peeled by treatment of the whole fruit in superheated steam followed by removal of the peels by abrasion in a modified potato peeler. At present, however, most pears for canning are peeled by either the Food Machinery Corporation peeler or the Ewald pear peeler. In the former the pear is placed in a cuplike carrier or is impaled on a forklike device by the operator, and it is then carried between safety-razor-like blades that remove the skin to a uniform depth. Other knives cut the pear in half and remove the core and stem. In the Ewald peeler the pear is held in a clamshell-like cup of the size of the pear. Knives of the contour of the fruit peel the pears to uniform size and shape. With both machines considerable hand trimming is required to remove bits of skin and blemishes. Recently (1957) a pear-peeling machine of new design, the Coons Pear Peeler of the Atlas Pacific Engineering Company, has been used successfully in several California canneries.

The waste during peeling, coring, and stemming is usually 30 to 35 per cent. The cores and peels can be used in the preparation of vinegar, brandy, or denatured alcohol, although in most factories the waste material is discarded by grinding and washing down the sewer with ample water. If dried, it is useful as stock feed. Some is used for making a refined juice to which is added sugar to give sirup for canning pears.

Until recently the waste peels and cores from canneries in the Santa Clara Valley in California were taken to a by-products plant for conversion into a dry feed for livestock. The plant is idle at present, largely because of the difficulty of realizing a profit on the operation.

Canning and Sorting. After peeling and coring the fruit is again sorted for quality. The pears are canned to advantage by semiautomatic, hand-

pack fillers or by hand from a sorting belt. Speed is essential in order to prevent browning by oxidation.

Siruping. The sirups used for the different grades are 40, 30, 20, and 10° Balling and water, respectively. Owing to the pear's low acidity, the 40° sirup is sufficient for the best grade, sirups higher in sugar than 40° Balling imparting too sweet a taste.

Sterilizing. In an agitating cooker, Bartlett pears in No. 2½ cans require a sterilizing time of approximately 17 min. at 212°F. and about 14 min. at 220°F. In nonagitating cookers at 212°F., the processing time is about 25 min.

Thorough cooling after sterilizing is necessary; otherwise some of the fruit is liable to turn pink in color, even more so than is the case with peaches. Chalkiness and yellow color indicate use of immature pears. Dark color of the surface is caused by browning after peeling and before canning.

PLUMS
(Prunus domestica)

The large, sweet varieties of white plums, such as the Green Gage and Yellow Egg, are in greatest demand for canning purposes; the red and black varieties are seldom used (see also fresh prunes in the next section).

The plums are sorted, and the stems and leaves removed, after which they are graded on vibrating screens containing circular openings of 32/32, 40/32, 48/32, and 56/32 in. in diameter. Fancy-grade plums are 56/32 in., Choice-grade plums 50/32, and Standard-grade plums 42/32 in. in diameter.

Plums soften badly in the sterilizing process so that it is difficult to obtain well-filled cans, and on account of their very high acidity there is serious danger of pinholing and corrosion of the tin plate unless the fruit is very thoroughly exhausted. The use of heavily coated tin plate, or of Type L plate, and the application of a thorough exhaust will greatly reduce loss by this type of spoilage. Plums are sterilized from 8 to 14 min. at 212°F.

FRESH PRUNES

In Oregon considerable quantities of the Italian variety of prune are canned in the fresh state. They are often labeled purple plums. Large well-ripened and well-colored prunes are washed, sorted, size-graded, and packed in heavily enameled cans, preferably of Type L or similar plate. Sirup of 40° Balling is desirable in order to counterbalance the high acidity of this fruit. Exhausting and processing are about as given for plums.

The Prune d'Agen, or "French Prune," of California is less desirable

for canning fresh. It should be picked from the tree firm-ripe and should then be lye-peeled, as the skin is tough and bursts during processing. A strong lye of about 10 per cent sodium hydroxide is required for peeling. The fruit may be packed in glass jars or in plain tin Type L plate cans in

FIG. 38. Semiautomatic hand-pack filler for fruits. (*Food Machinery Corp.*)

30° Balling sirup and exhausted at 200°F. for 4 to 6 min. The canned peeled prunes should be processed in an agitating cooker for about 20 min. at 212°F.

FIGS
(Ficus carica)

Figs are canned extensively in Texas and California, and small quantities are canned in some of the other Southern states, particularly Louisiana. In California two varieties are used for canning purposes, the Smyrna, or Calimyrna, and the Kadota. The Kadota, a white fig of moderate size, thin skin, firm flesh, and small seed cavity, is the more important canning variety. The Calimyrna, a Smyrna variety, is a very large variety which during its growth on the tree requires artificial pollination, or caprification, through the agency of the fig wasp, *Blastophaga*. The Smyrna is not so

desirable for preserving and canning purposes as the Kadota for the reason that its seeds are large, the flesh is thin and soft, and the skin is inclined to be tough. It is, however, very rich in flavor, high in sugar, and fairly satisfactory for canning. The Kadota variety has virtually displaced the Calimyrna for canning.

In Texas the Magnolia fig is most commonly used, and in Louisiana the Celeste. The Magnolia fig is light brown in color, of moderate size, and of excellent canning and preserving quality. The Celeste fig is very small and much elongated but, in addition to possessing a very rich flavor, is very firm and retains its form and texture remarkably well in preserving or canning.

California Process. Several methods are in use in California for the preparation and canning of Kadota figs. The Fresno-Merced district is the principal fig-growing area. The trees are pruned very low in order to permit picking of the fruit without ladders. It is picked frequently during the season, the desired maturity being firm-ripe, e.g., a degree of maturity slightly less than for drying or for eating out of hand. Shallow lug boxes are used, and the fruit taken promptly to the cannery in order to preclude deterioration in quality.

One large cannery used the following procedure in 1951. The figs were carefully sorted from a broad, slowly moving belt to remove overripe and split figs. These were sent to the dry yard. The more nearly perfect figs were washed very thoroughly in a long spray washer to remove dust; were again sorted, the ripest fruit going to the No. 10 can line and the firmer fruit filled from the belt into Nos. 2½, 303, or smaller cans and according to size of fruit; i.e., as the fruit was canned it was also size-graded by hand; the filled cans were heated on a metal-cloth conveyer in live steam at about 200°F. for 18 min. to wilt the fruit and remove undesirable flavors; a sirup of 48° Brix was added, which had been acidified with lemon-juice concentrate to reduce the pH value to about 3.8; the cans were exhausted in live steam for about 9 min. and processed in a continuous agitating cooker at about 212°F. for 45 min. for No. 2½ and smaller cans and 60 min. for No. 10 cans; and the cans were cooled in the usual manner. Subsequently the procedure was changed somewhat: blanching in the cans was done after filling them with hot water; they were then drained, siruped, sealed, etc., as above, and processed at 220°F. for 34 min. in a continuous agitating pressure cooker. The pH value after canning is in the neighborhood of 4.6.

In another plant the figs were size-graded on a roller grader, washed, sorted for quality and maturity, steam-blanched about 8 min., canned, siruped, exhausted, sealed and processed at 212°F. for 45 min., and allowed to cool in the air so that cooking in the can would continue for a while.

Various other procedures are in use, but those that have been outlined

above will suffice as illustrations. The blanching before canning or blanching in the cans before siruping serves to wilt the figs, expel air, and to remove a "raw" taste that may be evident if the blanching is omitted. If blanched in the cans in steam instead of water, much less of the natural sugars of the fruit is lost; hence a sirup of lower Brix can be used, with corresponding saving in cost of sugar. Acidification of the sirup is done in order to reduce the pH value to a level that will eliminate any danger of spoilage by *Clostridium botulinum*. The natural pH value of figs is in the range of 5.5 to 6.0, in which range *Cl. botulinum* and other heat-resistant spore bearers can grow.

The overripe and split figs sorted out before canning of the more nearly perfect fruit are placed on wooden trays, exposed to the fumes of burning sulfur for several hours or overnight in tightly constructed "sulfur houses," and dried in the sun. Drying of figs will be discussed more fully in the chapter on the sun drying of fruits.

Calimyrna figs can be prepared and canned in more or less the same fashion as outlined for Kadota figs. Much more careful sorting is required because of the tendency of this variety to undergo souring on the tree by yeasts, molds, and vinegar bacteria that gain entrance through the eye of the fig.

Texas Process. In Texas, according to Reed, some of the figs are peeled in a dilute lye solution and the peels are then removed in running water or under streams of water. The fruit is cooked in a heavy sirup before canning. Further details of this process will be given in the section on preparation of fig preserves, in Chapter 15. Figs are also canned in a medium sirup in a manner similar to that described for Kadota figs (see Reed).

ORANGES

Sliced peeled oranges were once canned in California for the use of seagoing vessels and for sale in England, but the demand has been limited. The process used was to heat the sliced peeled oranges in a heavy sirup, approximately 50° Balling, for several minutes at 175 to 185°F. The thoroughly heated fruit and sirup were then placed in cans and pasteurized at not above 185°F. The flavor of the oranges deteriorates after canning, and the product is not very palatable after several months' storage. Oranges are canned in Japan quite successfully, the Satsuma type being used.

POMELO, GRAPEFRUIT
(Citrus grandis)

Grapefruit is now canned commercially in Florida, Puerto Rico, and Texas for use as a breakfast dish. The grapefruit is size-graded either in a

sh-fruit packing house or at the cannery. The fruit is heated in hot ter a short time to soften the rind; this is then removed by hand, and fruit is segmented by hand. The segments may then be peeled by hand, aborious procedure. Experiments made at the University of California od Technology Department laboratory in 1915 proved that the segments y be peeled readily in a dilute lye solution. However, in most grapefruit nneries it is customary at present to lye-peel the whole fruit after moval of the rind and before segmenting, a procedure attributed to Fevre of the U.S.D.A. A 2 to 2½ per cent lye solution is applied, ually as a spray for 10 to 15 sec., and is followed by vigorous washing in ld water to remove disintegrated "skin," outer membrane, and adhering solution. The segments are next separated by hand with a bamboo or unt metal knife. They are then peeled by hand by use of a knife.

The peeled segments are sorted to remove broken and other defective eces. They are then placed by hand in cans, often with the convex surface the segment toward the can wall, in order to present a neat appearance d give a well-filled can. The fill in weight for a No. 2 can is about 17 oz. ie usual sirup is 40° Brix, but sirups of lower density are also used. It ay be added hot, 180°F. or less. The can lids are given the first seaming eration before exhausting.

The cans are thoroughly exhausted at about 180°F., sealed, and processed about 180°F. for 25 to 35 min. or at 212°F. for about 10 min., according one Florida canner. The cans of fruit may be prevacuumized and then cuum sealed, omitting exhausting by heat. Probably the can could be aled by the steam-flow or steam-vac methods after prevacuumizing. orrosion losses have been rather severe in the past when the canned fruit s been held too long in the warehouse or in the dealer's store. Thorough hausting and use of Type L plate appear to be desirable. Bitting states at for fruit not layered in the can a sirup of 35 to 40° Brix is desirable.

RIPE OLIVES
(Olea europaea)

Since the canning operation represents an incidental step in the preparation of ripe olives, a separate chapter will be devoted to the pickling and anning of this fruit (Chapter 9).

PINEAPPLES[1]
(Ananas sativus)

Pineapples were canned in Maryland in a small way early in the history f the canning industry, the fruit being shipped to the canneries from

[1] The author wishes to thank Dr. E. F. Cornell of the Hawaiian Pineapple Company r much of the information on pineapple canning.

FIG. 39. Battery of Ginaca machines. (*Dole Hawaiian Pineapple Co.*)

Florida, but the Hawaiian Islands, the Philippines, and the Malay Peninsula now produce most of the canned pineapple of the world.

Pineapples were first grown in the Hawaiian Islands for export in the fresh condition to the mainland, but it was soon found that the market for the fresh fruit was limited and that, in order to ensure arrival of the fruit in sound condition, it was necessary to pick it before it had reached maturity. The canning of the field-ripened fruit then followed as a natural sequence.

Growth of the Pineapple Industry. The increase in the production of canned pineapple since 1900 is shown in Table 17. The juice pack in 1956 was 14,500,000 cases.

Harvesting. The fruit is allowed to reach full maturity, not only for maximum flavor and quality but also so that the optimum canning cutout and yields may be attained. Workmen walk along the rows and pick the pineapples from the plants by bending the pineapple sharply. They then cut off the crown with a sharp knife and place the pineapple on a belt on an extended boom that carries it to a large bin on a special truck. The truck also moves the harvesting machine. When the bin is full the harvesting machine lifts itself off the truck by four hydraulic lift legs, and the

Table 17. Production of Canned Pineapple in the Hawaiian Islands Compared with Canned Peaches in California

Year	Pineapple, cases (1 case equivalent to 24 No. 2½ cans)	Peaches, cases
1909	9,800	907,000
1910	625,000	2,145,000
1915	2,700,000	3,239,600
1920	6,752,000	5,731,000
1930	12,672,000	13,771,000
1933	7,815,000	11,150,000
1941	10,188,000	12,733,000
1943	11,127,000	10,719,000
1945	10,164,000	13,105,000
1954	18,200,000	20,480,000
1956	18,500,000	31,826,000

truck drives the bin to the cannery or to the barge for transportation to the cannery. Another truck drives under the harvester, and the picking continues.

Most of the crop is picked in June, July, August, and September, although in the other eight months of the year there is usually enough fruit to permit canning operations for several days of the week on a partial-capacity basis.

The Ginaca Machine. The fruit bins from the fields are lifted mechanically from the trucks and conveyed to a central dumping station. The bins, each holding about 8 tons of fruit, are dumped, and the pines are graded mechanically for size; each size goes to a Ginaca machine adjusted to its diameter. This machine is entirely automatic in operation. It cuts a cylinder from the center portion of each fruit, removes the shell, cuts off the shell portions at each end of the cylinder, and removes the core. An "eradicator" scrapes the edible flesh from the shell as completely as possible for use in crushed pineapple or for juice.

Trimming. The cylinders from the Ginaca machine are conveyed by belt to the trimmers who inspect each cylinder carefully and trim away any small portions, such as the bits of adhering shell at the ends, unsuitable for canning.

Slicing. The trimmed cylinders are carried by chain conveyer through a spray washer to the slicing machine. This machine slices them transversely into rings ½ in. thick for No. 2½ cans and $^{25}/_{64}$ in. thick for No. 2 Tall cans.

Grading and Packing. The slices are carried by belt to the packers, women who inspect the slices and place them in the cans. Three grades, viz., Fancy, Choice, and Standard, are made on the basis of color, texture,

FIG. 40. Vacuumizing, siruping, and sealing cans of pineapple. (*Dole Hawaiian Pineapple Co.*)

and perfection of previous operations (workmanship). Broken and other pieces not good enough for canning as slices are conveyed to the shredder, the shredded material being canned later as crushed pineapple.

Prevacuumizing. The filled cans enter a vacuumizing chamber, where they are subjected to a vacuum of 25 in. for 5 to 10 sec. This operation removes air from the tissues of the fruit and changes the appearance from a chalky white to semitranslucency and gives it after canning a more uniform color.

Siruping. The cans are siruped in a conventional siruper like that used for canned peaches. The sirup is made up in part from juice expressed from the shells and other by-products. The juice is neutralized with lime, heated to throw out calcium citrate, filtered, treated in ion-exchange columns and partially concentrated *in vacuo*, before it is mixed with cane-sugar sirup and added to the cans of pineapple (see Chapter 23 for details). Citric acid is made from the calcium citrate.

Double Seaming. The cans are sealed under about 15 in. vacuum by the usual double-seaming operations. The prevacuumizing operation and sealing in vacuum make it unnecessary to heat the cans of fruit in an exhaust box.

Processing. The cans of pineapple are processed in continuous pressure cookers at a temperature somewhat above boiling until the center temperature of the cans reaches 195°F. The length of process will vary with the size of can and other conditions from about 7 to about 10 min. The cans are cooled in water and are trayed and stored in the cooling room until required for labeling and casing.

Crushed Pineapple. The shredded material previously mentioned is pumped into steam-jacketed kettles and heated to 195°F. Some of the juice is drained away to give a product of optimum consistency. If it is to be sweetened, sufficient heavy sirup is added to give the desired sugar content. The hot mix is packed into cans automatically, sealed, given a short process to ensure keeping quality, and cooled.

Juice. See the chapter on juice for details.

By-products. Shells, trimmings, and other by-product material are shredded and pressed in a continuous press to recover as much juice as possible. The juice is refined as previously mentioned and is used in canning of the pineapple after mixing with cane-sugar sirup. The press cake is dried in rotary drum driers, and the dried product sold as "pineapple bran" for feeding to livestock. Citric acid is recovered from the juice, as previously described (see also Chapter 24).

FRUITS FOR SALAD

The packing of mixed fruits for use in salad and dessert has become a fairly important part of the fruit-canning industry of California, the output being about 1 million cases per year. It was formerly labeled "Fruit Salad," but the Federal Food and Drug Administration ruled that it is not a salad but rather a mixture of fruits that may be used in preparing salad; hence the present designation, "Fruits for Salad."

Bartlett pears and clingstone peaches are prepared as for canning, by halving and peeling or coring. The peaches are given a preliminary steaming to soften them sufficiently so that they will be of proper texture when processed with the other fruits in the canned fruits for salad. Most of the halves of pears and peaches are cut in half lengthwise; some for small cans may be cut in thirds. Canned sliced pineapple cut to give 16 segments per slice is used. Number 10 cans of apricots also are opened, these having been canned firm-ripe in season, usually in a Choice-grade sirup, and given a slight processing, sufficient to prevent spoiling but not sufficient to soften them unduly. Maraschino cherries, dyed with erythrosin dye as described in Chapter 15, are prepared in bulk during the season for canning fruits for salad or are purchased in bulk from local preservers.

The sirup from the canned pineapple and apricots is recovered, mixed with a filter aid, such as Hy-Flo infusorial earth, filtered hot, and then

mixed with sufficient water and sugar or cane-sugar sirup to give the sirup required for canning the fruits for salad, or in some cases it can be used after straining to remove coarse particles of fruit.

The assembly-line system is followed in canning. Cans or jars are conveyed by straight-line conveyer, and as they pass before the filling crew each girl adds the required number of pieces of the variety of fruit for which she is responsible. One sequence consists in adding peaches first, then pears, apricots, Maraschino cherries, pineapple segments, and last, one or more pieces of peach to top the filled can and give the desired fill in weight.

Sirup is then added by siruping machine, and the cans are exhausted, sealed, and processed in an agitating continuous cooker. For No. 1 Tall cans the process is about 10 min. at 210 to 212°F., and slightly longer for the No. 2½ can. Exhausting should be thorough. However, pre-vacuumizing and steam-flow seaming can be used. In one large cannery glass jars are used and are sterilized at 218°F. in a continuous pressure retort at 20 lb. total pressure. They are also cooled under air pressure in order to hold the lids in place.

The Canners' League of California has established the following specifications for Fancy and Choice grades of canned fruits for salad.

Fancy Fruit for Salad. Fruit should be of good color, ripe yet not mushy, of uniform size, symmetrical, and free of blemishes serious for Fancy-grade fruits. Apricots, Bartlett pears, and yellow cling peaches must be at least equal to Fancy tidbits. The Maraschino cherries must not be smaller than seven to the ounce. The apricots must be in halves; pears and peaches in halves, quarters, sixths, or eighths; pineapple in sectors; and the cherries whole. The apricots constitute 18 to 30 per cent, pears 21 to 33 per cent, peaches 24 to 40 per cent, pineapple 9 to 16 per cent, and cherries 4 to 8 per cent of the total drained weight.

The sirup after canning and reaching equilibrium with the fruit must be at least 24° Brix (or Balling), with a permissible tolerance for any single package of 10 per cent; i.e., it may be as low as 21.6° Brix.

Choice-grade Fruits for Salad. The specifications are similar to those for the Fancy except that the California fruit must be at least equal to the regular Standard canned fruit in quality and the pineapple equal to or better than Standard tidbits. The sirup after canning must test 20° Brix or above with a tolerance of 10 per cent, i.e., not below 18° Brix for any package.

FRUIT COCKTAIL OR FRUIT STARTER

In 1920 to 1925 the Fruit Products Laboratory of the University of California packed for local distribution and sale a mixture of diced fruits

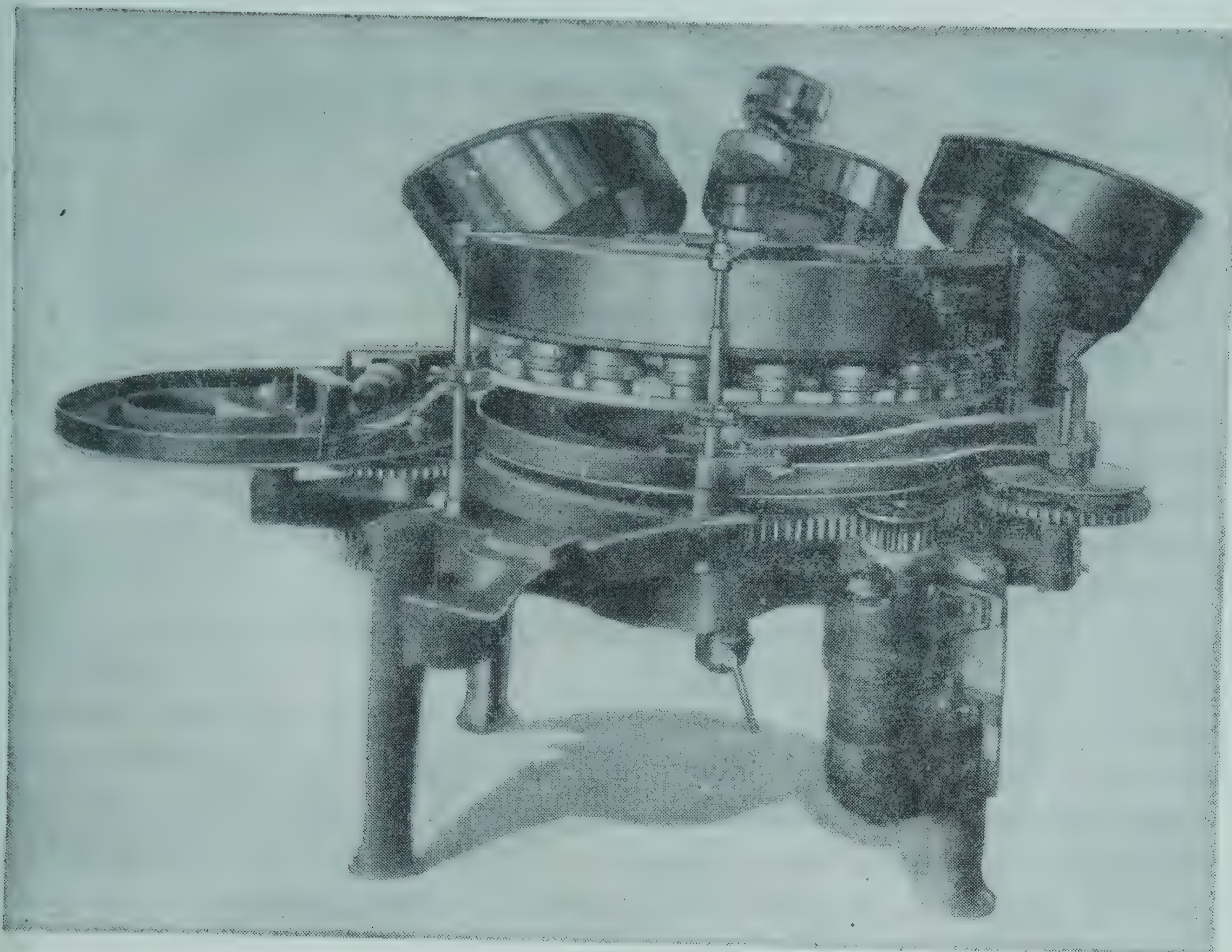


FIG. 41. Fruit-cocktail filling machine. (*Food Machinery Corp.*)

in medium sirup under the label of "Fruit Cocktail." Sales and interest were excellent, indicating that the product might meet with popular favor. Several years later the product was packed by a small cannery, that of H. E. Gray, near San Jose, Calif. It was immediately successful and has since become a regular item in all large California fruit canneries. The 1955 pack was 13,178,000 cases, according to *Western Canner and Packer*.

During the Bartlett pear–yellow clingstone peach season these fruits are peeled, halved, pitted or cored, and diced by machinery to give pieces that will pass through a ¾-in. opening. Maraschino cherries are cut approximately in half by machine. Canned pineapple slices are cut in segments. Thompson seedless (Sultanina) grapes are stemmed by machine, sorted, washed, and graded for size. The stemmer is similar to that used for cherries. The cut fruits are sorted to remove unfit pieces.

The diced pears and peaches are mixed automatically and continuously on their way to the filling machines in some plants; in others they are not mixed before addition to the can. Approximately twice as much peach as pear is added per can. The mixing of the fruits and filling of the cans are done for the most part by an ingenious automatic machine. Sirup suitable for the grade is added; the cans are exhausted and then processed for about 20 min. at 210 to 212°F. in a continuous agitating cooker or for about 15

to 16 min. at 220°F. in a continuous pressure cooker. Prevacuumizing plus steam-flow seaming can be used. Glass jars of fruit cocktail are given about 18 min. at 220°F. in a continuous pressure cooker with added air pressure to give a total pressure of 20 lb. per sq. in.

Fancy Fruit Cocktail. The Canners' League specifications for this grade are as follows: Peach and pear pieces must be characteristically cubical to right-triangular pyramidal in shape, of such size that they will pass through a square ¾-in. opening; and they must not exceed ¾ in. in length. The grapes must be of at least Choice quality. Peaches must constitute not less than 30 per cent or more than 50 per cent of the total drained weight; pears not less than 25 per cent or more than 45 per cent; grapes not less than 7 per cent or more than 14 per cent; and cherries not less than 2½ per cent or more than 6 per cent.

The sirup after canning must test at least 24° Brix; a 10 per cent tolerance is permitted for any single can.

A tolerance of 15 per cent by weight of pieces of peaches that do not conform to the specified sizes and 10 per cent for pears is permitted.

Choice Fruit Cocktail. The Canners' League specifications are similar to those for the Fancy grade, although the pieces may be somewhat smaller. The sirup after canning must test at least 20° Brix (with a 10 per cent tolerance). A tolerance of 20 per cent by weight is permitted for the various fruits that do not conform to the size and shape specified.

Fruit Mix. Considerable fruit mix, consisting of diced peaches, diced pears, and whole Thompson seedless grapes, is canned in the same manner as fruit cocktail. The cherries and pineapple are omitted. The 1954 pack was 193,000 cases, and in 1955 was 253,000 cases, according to *Western Canner and Packer*.

CANNED CRUSHED FRUITS OR SAUCES, OTHER THAN APPLE

The canning of crushed pineapple has been discussed in this chapter under pineapples. Crushed-fruit preserves are used extensively by the ice-cream industry and are discussed in Chapter 15. Experiments conducted by the staff of the Fruit Products Laboratory in cooperation with commercial canners have demonstrated that there is considerable consumer interest in canned crushed fruits in a medium sirup for use as a breakfast sauce, or in various desserts such as pies, whips, gelatin desserts, and puddings. "Sauce" is perhaps a better term.

Peaches, pears, or apricots are prepared as for canning. They are then ground coarsely in a large-sized food grinder equipped with a plate with ½-in. openings. Cans are filled about three-fourths full with the ground

fruit, and sirup of 40° Brix is added to fill the can; or preferably the sirup may be added to the cans first and fruit then added to fill.

The cans must be given a long exhaust in live steam, 10 to 12 min. at 200 to 212°F., since heat penetration is very slow, or the filled cans could be prevacuumized and sealed in steam or vacuum.

They are then sealed and given a process at 210 to 212°F. of about 10 to 15 min. for apricots, 15 to 20 min. for cling peaches, and about 20 min. for pears, in an agitating cooker. If cans are sealed cold, at least 5 min. more should be allowed. An alternative method consists in adding 1 lb. of sugar to 6 or 7 lb. of the ground fruit, heating to boiling, canning hot, sealing, and processing at 212°F.

Figs may be canned in similar fashion but because of their low acidity require a process of 1½ hr. at 210 to 212°F. in a nonagitating cooker, or they may be acidified sufficiently to give a pH of less than 4.5, determined after processing.

These fruits are much less sweet than fruit jams or preserves and can be eaten in generous servings. They are satisfactory not only for household use but also for commercial use in ice cream, ices, bakery products, and as candy bases.

FRUIT PURÉES

Fruits in the form of purée are canned in small cans as foods for infants. There may be a potential demand for such products in larger cans for general household use and for use in soda fountains, bakeries, and ice-cream factories. See the section on sieved fruits for baby foods at the end of this chapter.

Fresh fruits are prepared as for canning and are then steamed until soft, when they are passed through the fine screen of a tomato-juice extractor, through a tomato cyclone as in making tomato purée, or through an Enterprise disintegrater or similar hammer mill. In order to give a smooth consistency the purée should be passed through a tomato-catsup finisher.

It may be canned sweetened with about 1 lb. of sugar to 6 or 7 lb. of purée, or it may be canned without added sugar. Most fruit purées are very thick; consequently heat penetration is slow. It might be advisable to heat them nearly to boiling in an open kettle or in a continuous stream in a steam-jacketed pipe. The contents of small cans should be about 180°F. when sealed, and No. 10 cans about 160°F. At these sealing temperatures, the processing period need be only about that for the corresponding canned whole or halved fruits.

The lightly sweetened purées are excellent for household use in frozen

desserts, in homemade milk shakes, etc. The unsweetened purée in No. 10 cans is often used commercially in the making of jams.

DICED FRUITS

Some cling peaches are diced, canned in a 25 or 40° Brix sirup, and processed about 16 min. at 228°F. or about 25 min. at 212°F. Pears are also packed in a similar manner.

APPLESAUCE

Canned applesauce has met with favorable response, the total United States pack being 13,017,000 cases, 2,009,000 cases in the Western states in 1955, according to *Western Canner and Packer*.

In California the Gravenstein variety chiefly is utilized for the production of sauce and is grown in the vicinity of Sebastopol, about fifty miles north of San Francisco. It ripens in late July and August, and formerly most of the crop was shipped to the Middle West and Eastern United States for sale in the fresh condition. At present most of the crop is made into sauce. It is believed that the Barlow Bros. Canning Company was the first to can applesauce by the method now in use. After the Gravenstein season is ended, certain other varieties are made into sauce. A variety that is rather tart in taste and which gives a sauce of light color, pleasing texture, and pronounced apple flavor is preferred. See varieties recommended for canning earlier in this chapter.

One process of making sauce in California consists in first washing the apples thoroughly; sorting to remove apples that are unsuitable for sauce; peeling and coring by a machine such as the Peas, fed by hand but motor-driven; wetting the peeled and cored fruit with a dilute brine to check browning of the color by oxidation; trimming and sorting from a slowly moving belt; rinsing with water in a revolving reel to remove salt from the surface; chopping or slicing by machine; cooking in a continuous cooker with steam and at the same time adding continuously the required amount of syrup of 67° Brix (liquid sugar); pulping in a machine similar to a tomato pulper, which removes any remaining seed cells, coarse fiber, etc.; inspection as the sauce flows over a brightly illuminated transparent plate and removal of any small specks ("despecking"); continuously heating to 192 to 195°F.; canning at this temperature in an automatic, high-speed filling machine; double-seaming the cans and then cooling in a long tank of running cold water. Because of the thick consistency of the sauce, cooling is very slow, about 30 min. being required to reduce the temperature to 100°F. The cans may be dried on a conveyer and are then either labeled and cased or are cased unlabeled to be labeled later.

In a modification of this procedure the peeled, cored, and trimmed apples are sliced or chopped and then cooked; after cooking they are pulped and then heated with heavy sirup and canned.

The No. 303 can is generally used for the household trade, and the No. 10 for institutional users such as restaurants, hotels, hospitals, and the military. The soluble-solids content of the sauce should be in the range of 18 to 20 per cent as determined by examination in an Abbe refractometer, but will vary somewhat with variety and maturity. Throughout the canning day, numerous samples are taken from the line for examination in the laboratory by refractometer and for checking the quality.

In practically all plants sucrose sirup of 67° Brix, so-called liquid sugar, is used in place of the dry sugar, care being taken to prevent undue dilution of the sauce by the water of the sirup.

CANNED PIE FRUITS FOR HOME USE

The canning of pie fruits for use by commercial bakers has been described elsewhere (see canning of peaches). Until recently, however, there has been no similar product in smaller cans, Nos. 2½ and 2 sizes, for use in the home as pie fillings. At present several canneries are packing canned pie fruits for home use. Usually the fruit is canned in a medium sirup thickened with a special starch that does not form a stiff jelly. An extensive investigation has been conducted by Strachan and coworkers at the Agricultural Experiment Station in Summerland, B.C., Canada, on the preparation and canning of British Columbia fruits in suitable form for use in homemade pies.

They recommend that as little water as possible be used and that the total length of heating of the fruit and other ingredients should not exceed 6 min., so that the fruit will not be "mushy" or the mixture too watery. They compared a considerable number of thickeners and concluded that a mixture of two or more gave a better consistency than a single thickener. The thickening agents are added near the end of the preparatory process. As the cans are filled with the scalding-hot mix, no additional sterilization is required.

Their recommended procedure for freestone peach pie filling will illustrate the general method found best at present. The investigation is still under way. The peaches are picked at the firm-ripe stage, pitted, steam-peeled, and cut in quarters or large slices. The formula consists of peaches 80 lb., sugar 20 lb., Minute tapioca 2 lb., Amaizo W-13 starch 4 oz., locust gum 1½ oz., and citric acid 3 oz. With these ingredients is used 15 to 20 lb. of water, enough to dissolve the sugar, acid, and thickeners and to prevent scorching. To one-third of the sugar the thickeners and acid are added and mixed thoroughly; the remaining two-thirds of the

sugar and the water are added to the fruit, and the mixture heated to about 190°F. quickly with continuous stirring. While stirring and heating this mixture the previously mixed sugar and thickening agents and acid are sifted in and the mixture heated to 209 to 210°F. The cans are filled with the hot mix, sealed at once, and inverted to cool. They should cool thoroughly in water, to about 100°F.

A single thickening agent such as the nonjellying starch may be used instead of the mixture given in the formula. The tapioca is an excellent thickener, although if the granules are of the usual size sold for home use, the resulting rather large globules ("eyes") might not appeal to the average consumer; therefore if tapioca is used it should be the fine-grained type. There are several brands of nonjellying so-called waxy maize starches, any one of which may be used. Locust gum in the small amount called for in the formula adds brightness to the filling.

Strachan et al. recommend that in preparing apples for home pie fillings a mixture of applesauce, not to exceed 25 per cent, and deaerated sliced apples be made. Since the applesauce acts as a thickener, less of the added thickening agent is required. One of their formulas is as follows: deaerated sliced apples 60 lb., applesauce 20 lb., sugar 20 lb., Amaizo or other pie-thickener nonjellying starch 8 oz., locust bean gum 1½ oz., and water 10 to 15 lb. The procedure is about as directed for peach-pie filling. The apples are prepared by peeling, coring, trimming, slicing, holding under a high vacuum of at least 27 in. for about 6 min. to deaerate them, and releasing the vacuum with steam to blanch the apple slices. The sauce is made in the usual manner, as described earlier in this chapter.

Apricots are pitted and cut in quarters but not peeled; berries are used in the whole form after sorting and washing. Care must be taken not to overcook the berries by too prolonged heating.

The authors state that a simpler procedure that has been used commercially is as follows: The prepared raw fruit is added to the cans as in ordinary canning, and then a partially precooked slurry made up of water, starch, sugar, and any other essential ingredients is added by automatic siruper to fill the cans. The cans are sealed under vacuum or prevacuumized and sealed in steam, as previously described. The cans are then processed in a continuous agitating sterilizer for a sufficient time to cook the fruit and thickening agent. They are then thoroughly cooled in water in the usual manner. This procedure gives a product in which the fruit is "set" in a clear gel. It is attractive in appearance, and the cost of production should not be much greater than for canned fruits in sirup (ordinary canned fruits). An agitating processor (sterilizer) is required in order to mix the ingredients during sterilization and to give a smooth clear gel.

Cruess, Musco, and Binder have reported on experiments on the prepa-

ration and canning of raisin-pie fillings. One formula recommended by them is as follows: raisins 29 lb., water 59 lb., waxy maize nonjellying starch 2.0 lb., sugar 10 lb., and citric acid 0.4 lb. Heat the raisins in about three-quarters of the water to boiling for 2 to 3 min.; set aside until the raisins become plump, usually 2 to 3 hr. Dissolve the sugar and acid in the remaining water by heating to about 120°F. and stirring; then add the starch slowly with stirring and heating, but do not heat above 130°F. Add it to the raisins, with constant stirring; heat to about 200°F.; can scalding hot; seal cans and process at 212°F. for 30 min.; cool in running water 20 to 25 min., as the filling cools very slowly. A variation consists in using a mixture of about equal parts by weight of sliced apples and raisins.

CANNED DRIED FRUITS

During the hot summer months, dried fruits in boxes or cartons do not keep well because of excessive drying out, sugaring, molding, and attack by insects. The same is true in the tropics at all seasons. Consequently there is a place in the marketing scheme for dried fruits packed in tin or glass, so that the undesirable changes mentioned may be prevented and the distribution of dried fruits thus may be extended to the summer months and the tropics.

Ready-to-serve Dried Prunes. The procedure as developed by E. Mrak at the University of California is as follows: Large-size, unprocessed dried prunes of the Prune d'Agen (French prune) variety, previously graded for size, are carefully sorted, thoroughly washed, and heated in boiling water for 3 to 5 min. They are rinsed and then packed in Type L cans or cans of similar plate. The "going-in" weights of the processed prunes are 3 lb. per No. 10 can and 14 oz. per No. 2½ can, weights for other cans being in proportion.

Sirup of about 20° Balling is added to fill the can; then the cans are exhausted 16 min. at 200°F. or above, sealed, and processed 45 min. at 212°F. A generous head space, about ⅜ in., should be left to provide for accumulation of hydrogen gas, as prunes attack tin plate actively. Type L cans should be used.

Corrosion is much less severe, and the shelf life of the canned product is greatly prolonged if the sirup used in canning is acidified with 0.40 gram of citric acid per 100 cc. or with an equivalent amount of concentrated lemon juice.

If the sirup is of too high a sugar content, the canned prunes will be shriveled in appearance and tough in texture.

The Canners' League specifications call for the following drained weights at 30 days, or longer, after canning:

Can	*Oz.*
3-in. 8-oz.	6¼
3¼-in. 8-oz.	6¾
Picnic	8
No. 1 Tall	12
No. 2 Tall	15
No. 2½	22
No. 10	79

The sirup must be not less than 20° Brix at time of canning.

According to Mrak, if a sirup of 20° Brix is added, it will increase to about 40° Brix after canning, as the fruit is much higher than the sirup in sugar content.

So-called "Dry-pack" Prunes. Mrak recommends the following procedure for this product: French-variety dry prunes of 50 to 60 size are processed in boiling water for 4 min., drained, and packed scalding hot in enamel-lined cans. The lids are placed on cans and given the first rolling operation; the cans are exhausted 20 min. in live steam and sealed. They are allowed to cool in the air. These prunes are for cooking later with water and serving in the usual manner.

Another siruples product developed by Mrak and Cruess is canned at a rather high moisture content in order that the fruit may be eaten out of hand satisfactorily without further treatment. The dried prunes are graded for size and are then cooked in boiling water until the flesh attains about 32 to 33 per cent moisture. After a few trials a cooking time can be established that will give this moisture content. The scalding-hot prunes are packed into double-enameled Type L plate cans; but they should be packed rather loosely in order to minimize pinholing and hydrogen swelling. The cans are exhausted at 200 to 205°F. for 5 or 6 min., sealed, and processed at 212°F. for about 30 min. for small cans such as 8 oz. and No. 1 Tall. Number 2 and 2½ cans should be processed 40 to 45 min. and then cooled thoroughly. Key-top cans may be used if desired. These prunes are greatly relished by children as a between-meal food. They have the advantage also that 5 to 10 min. boiling in water, or water with a small amount of added sugar, cooks them sufficiently for serving as breakfast prunes. Another procedure consists in heating the dry prunes in a sirup of 30° Brix to boiling and allowing them to stand several hours, draining, and canning dry-pack style as above.

Canning of Raisins. At one time the Kings County Packing Company of Armona, Calif., canned seeded Muscat raisins for distribution in the tropics or during the summer months. Canning prevents losses from heat and insects and preserves the raisins at their moisture content at time of canning.

Considerable spoilage was encountered from fermentation and separation

of dextrose crystals after canning. Parcell at the University of California established that fermentation was due to yeast that survived the very mild pasteurization used by the cannery and that separation of dextrose crystals was caused by too low a moisture content.

An improved procedure based on his experiments was about as follows: The raisins as received from the grower were stemmed by machinery and were dried to a low moisture content, about 8 per cent, at 145°F. Higher drying temperatures volatilized the Muscat aroma and caramelized the flesh. They were then "cap-stemmed" (treated by machine to remove the small stems on each raisin). Next they were heated in hot water and seeded by machine. The seeded raisins were packed into 8- and 12-oz. cans, and sufficient water was added as determined by experiment to give 33 per cent moisture.

The cans were exhausted at 180 to 185°F. for about 10 to 12 min., sealed hot, and processed at 180°F. until heated to the centers, usually about 30 to 35 min.

While temperatures of 200 to 212°F. may be used for exhausting and processing, the flavor is injured less at 180 to 185°F.

Seedless raisins also were canned successfully by a similar procedure.

It is advisable to use Type L plate cans, since the raisins react rather severely upon common coke plate and will in time cause hydrogen swelling. For the same reason considerable head space should be left and cans sealed at not less than 175°F.

Figs. Unsulfured dried figs may be canned very successfully by the procedure outlined for high-moisture dry-pack prunes.

Sulfured Fruits. Sulfured dried fruits act very severely upon plain tin plate, causing detinning, blackening, and hydrogen swelling. In heavily enameled cans they may be packed fairly satisfactorily under high vacuum. They should be of fairly high moisture content, about 22 to 24 per cent.

The major difficulty is that after a few months' storage the sulfur dioxide content of the fruit drops to a level at which darkening occurs, thereby shortening the shelf life of the product materially.

Natural-condition Dried Fruits. Raisins and prunes have been canned at natural moisture content (about 16 per cent for raisins and about 22 to 24 per cent for prunes). A small measured amount of epoxide fumigant is added to each can to sterilize contents. Other dried fruits can be packed in this manner. No heat is applied.

BAKED CANNED FRUITS

At various times in the past canners have attempted to can baked pears and apples. Nichols of the University of California Food Technology Laboratory developed a satisfactory procedure for baking and canning

pears. The firm-ripe pears were cut in half and placed on upright steel skewers on a metal conveyer and were carried through a bread-baking oven to bake them to a brown color. They were canned in a heavy spiced sirup. A more pleasing product is made by sprinkling the cut surface of the fresh pears with sugar and baking in shallow pans as is done in the home, then canning in a spiced sirup.

Some apples are peeled, cored, halved, sprinkled with sugar and spices, baked, and canned in sirup. Pears may be canned in similar fashion.

Pears for baking may be canned in halved, cored, but unpeeled condition in 40° Brix sirup. The process is about 30 min. at 212°F. Whole cloves and stick cinnamon may be added at the time of canning.

SIEVED FRUITS FOR BABY FOODS

The preparation and canning of sieved and of chopped fruits and vegetables as well as other food products, as foods for babies and small children, has become a very important industry. Several large canners supply the lion's share of the market.

Most of the pack is prepared from the raw fresh material and canned in the baby-food canneries themselves. In a typical baby-food cannery, operations continue throughout the year, since the full line includes meat and cereal as well as fruit and vegetable products. As many as 50 different items may be packed by a single plant, and new products are being added to the list frequently.

General Requirements. Baby foods must first of all be wholesome and easily digestible. For that reason they must be free of toxic substances such as metallic spray residues and DDT. They must not be rough in texture and fibrous, or they will irritate the infant's digestive tract. They must be above suspicion as to bacterial contamination and products of bacterial decomposition.

They should furnish the vitamins, minerals, proper proteins, and carbohydrates in proper amounts. For example, except for use as a dessert, a baby food consisting wholly or chiefly of cornstarch, sugar, and flavoring would not be suitable. One made up of sieved apricot, orange juice, and a little farina as stabilizer would be very appropriate, as it would furnish vitamin C of orange juice, carotene of apricot, basic minerals of both products, and the blood-building properties of apricots. Sieved peas and sieved carrots or a blend of the two are valuable baby food; the peas for their protein and B vitamins, the carrots for their carotene content.

In the so-called "junior foods" or "chopped foods" for older babies and young children, the vegetables, fruits, and meats are ground more coarsely than for baby foods, and more meat is included in some of them.

Meat and vegetable may be combined; but fruit and meat are not canned together at present.

Size of Containers. For infant feeding the sieved foods are packed in very small cans, viz., 202 × 214 size for regular sieved baby foods, 210 × 211 size for "junior" foods, and 202 × 202 size for sieved meats. Jars are of 4.85 fl. oz. size for sieved baby foods and of 7.95 fl. oz. for "junior" (finely chopped) foods. The small container permits the mother to feed the entire contents of the package before the product has had time to spoil. The junior foods are packed in containers of 6½ oz. or somewhat larger. The process time is usually about 5 min. longer than for the smaller container.

Sieved Apricots. While the operations and equipment differ somewhat in various plants, the following more or less composite procedure gives the more important steps.

Fresh whole ripe apricots are emptied from lug boxes into a small tank of water from which they are elevated to a spray washer, from which they proceed to a broad, slowly moving sorting belt. Here green, overripe, and otherwise unfit fruit is removed. The sorted fruit is then very thoroughly washed by sprays of water under fairly heavy pressure. The whole apricots are then cooked thoroughly by live steam 6 to 8 min. in a tubular or other continuous heater. They are then pulped in a stainless-steel heavy-duty cyclone-type pulper with fairly coarse screen. Copper and other heavy metals soluble in the fruit pulp are avoided. The pulper removes pits and coarse fiber. The resulting coarse, hot purée then is passed through a fine-screened finisher to remove small pieces of fiber and to give a fine-grained, smooth purée. It is then passed through a homogenizer to impart a smooth consistency, and then deaerated under high vacuum. The deaerated purée is then flash-heated in a closed continuous pasteurizer to 240°F., cooled in this system to 200 to 205°F., filled into cans at that temperature, and sealed and cooled in water in the usual manner. The jars are sealed by a high-speed jar sealer. All machines, conveyers, and operations must be highly synchronized, otherwise costly delay because of pile-ups and breakdown will occur. In another procedure the cans are filled hot, sealed, and processed in a continuous pressure cooker at 220°F. for 15 min., followed by 10 min. of cooling. They are then dried naturally as they travel by zigzag conveyer to the warehouse, a distance of 100 ft. or more. They are labeled by high-speed automatic labeling machine and cased semiautomatically, and the cases are sealed and warehoused. If a product of thicker consistency is desired, a small amount of farina, a cereal product, may be added and cooked a short time with the purée before canning. Sugar may be added to give the proper balance in flavor between the acidity of the fruit and the sweetness of naturally occurring and added sugar.

Sieved Peaches and Pears. Cling peaches and pears are pitted or cored and peeled as for canning. They are trimmed, sorted, precooked in steam, pulped, finished, precooked, and canned and processed as described for apricots.

Prunes. Usually the dried prunes are used, although they are inferior to the fresh in flavor, color, and vitamin C and carotene content. The dried prunes are sorted, washed, soaked in water to cover, cooked until soft, pulped as for fresh apricots, finished, standardized as to moisture or solids content, preheated, canned or glass-packed, processed, and cooled.

If fresh prunes are used, the procedure is as for apricots, except that cans of corrosion-resistant tin plate, such as Type L, is advised.

Apples. Apples are washed, cored, sorted, and heated in steam under 45 to 55 lb. pressure for about 50 to 55 sec., whereupon the pressure is released instantaneously. The Food Machinery Corp. or Pfaudler Company peelers are used. The accumulated steam pressure beneath the skins "explodes" the skins from the fruit, or at least loosens them. Passage through a rotating-cylinder spray washer removes the loosened peels. In one California plant the ensuing procedure was about as follows. The apples are trimmed and sorted, wet with dilute brine to arrest darkening, precooked in steam, and are ground coarsely, pulped, and finished. The sieved fruit is sweetened, preheated, and mixed in a steam-jacketed tank, filled hot, sealed, processed about 15 min. at 220°F., and given 10 min. water cooling, or the cans or jars are processed at 212°F. and cooled.

Blends. A blend of sieved apricots and apples is popular. The apples furnish acidity, and the apricots carotene. The blend is slightly sweetened.

Other blends are pears and peaches; pears, peaches, and apricots; apricots and peaches; and pineapple and pear. There are many other possible combinations.

Laboratory Control. The soluble-solids content and consistency of the sieved fruits are determined regularly in order that these properties will be as uniform as possible. Vitamin C assays and pH values are also determined on some samples. Consistency is extremely important and is closely controlled.

Note on Canned Specialities. The trend at present is strongly in the direction of canned specialities and novelties such as canned juices, fruit cocktail, fruits for salad, sieved fruits, crushed fruits, etc. Canners should keep abreast of such developments and be prepared to take advantage of them.

Retention of Nutrients in Canned Fruits. Cameron et al. (1955) have given an excellent summary and review of research conducted by various laboratories, including those of the National Canners Association on the retention of vitamins and other constituents during the canning of various foods. In general, loss of vitamin C, thiamin, and other water-soluble

vitamins is slight in unpeeled fruits. For example, apricots retained from 76 to 97 per cent of their ascorbic acid content and an average of 85 per cent in the National Canners Association experiments. Lye peeling resulted in moderate loss of C and B_1 but very little loss of niacin. Freestone peaches lost more of C than did cling peaches, the losses ranging from 14 to 28 per cent in steam peeling and 30 to 41 per cent in peeling and canning.

Citrus juices retained most of the ascorbic acid of the fresh juice. Retention ranged from 95.1 to 100 per cent for the orange-juice samples and 94 to 102.1 per cent for the grapefruit juices. The 102.1 per cent retention may indicate formation of other reducing substances during heating. The other water-soluble vitamins were also retained in high degree in these juices.

Tomato juice is a vegetable product, but its retention of vitamins is covered in Chapter 16, Tomato Products.

Carotene was well retained in all the fruits, and juices reported upon by Cameron et al.

Apparently other nutrient substances found in fruits, such as minerals, proteins, and carbohydrates, are well retained in the canning of fruits.

Dietetic Canned Fruits. For use in low-calorie diets fruits packed in water are used extensively and are packed by many fruit canners. Canned and bottled fruit juices are usually included in diets of patients who are on a liquid-foods diet. On a low-calorie diet the patient may require supplementary vitamins. Juices low in sodium can be prepared by treatment with a cation resin accompanied by adjustment of the pH value after cation-resin treatment. Low sodium diets are fairly common.

Instead of packing fruits in water for use in low-calorie diets or for use by diabetics, an artificial sweetener is sometimes added to the water used in packing the product. Saccharin and sucaryl are permitted by the food and drug regulations and are many times sweeter than sugars. To some consumers, including the present author, products containing added saccharin taste bitter instead of sweet. The canner should first make experimental packs of fruit sweetened with saccharin or sucaryl in order to establish the best amount of sweetener and best procedure in canning.

For further information on dietetic canned foods see *National Canners Association Bulletin*, 1953, on this subject, listed in references under the authorship of Cameron and associates.

REFERENCES

ALLEN, F. W., and CLAYPOOL, L.: Modified atmospheres in relation to the storage life of Bartlett pears, *Proc. Amer. Soc. Hort. Sci.*, **52**, 192–204, 1948.

BIGELOW, W. D., RICHARDSON, A. C., and BALL, C. O.: Heat penetration in processing canned foods, *Natl. Canners Assoc., Research Lab., Bull.* 16-L, 1920.

BITTING, A. W.: "Appertizing, or the Art of Canning," The Trade Press Room, San Francisco, 1937.

Boehringer, C. H.: Pineapple canning in Malaya, *Canner*, Oct. 11, 1930, pp. 13, 16.

Boschin, W. E.: Handling glass containers in the processing plant, *Canner*, **100**, 16, 18, 20, 30, May, 1945.

Cameron, E. J., and Associates: Retention of nutrients during canning, National Canners Association, 1955. A bulletin.

Campbell, C. H.: "Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

Chace, E. M., and Sorber, G.: Ripening pears with ethylene, *Canner*, Sept. 15, 1928, pp. 15–17.

Cling peach canning at Matmor, *Western Canner and Packer*, **37**(10), 72–75, October, 1945.

Cruess, W. V., and Musco, D.: Canning of raisin pie filling, *Canner*, May, 1951.

———, Quin, P. J., and Mrak, E. M.: Observations on the browning of canning peaches, *Fruit Products J.*, October, 1932.

Culpepper, C. W., and Caldwell, J. S.: Canning quality of eastern peaches, *U.S. Dept. Agr. Tech. Bull.* 196, October, 1930.

Darrow, G. M., Wilcox, R. B., and Beckwith, C. S.: Blueberry growing, *U.S. Dept. Agr. Farmers' Bull.* 1951, 1944.

Dow, G. F., and Associates: Producing blueberries in Maine, *Maine Agr. Expt. Sta. Bull.* 479, March, 1950.

Ewald, M.: Harvesting, handling and ripening of Bartlett pears for canning, *Western Canner and Packer*, June, 1935, pp. 11–21, 41.

Farrell, A.: Pineapple canning, *Food Inds.*, April, 1931, pp. 144–148.

"Flow Sheets of Food Processes," *Food Engineering*, 1955. A handbook.

Gavrilova, C.: Ripening of canning pears, *Canner*, May 20, 1944, pp. 16, 18.

Hendrickson, A. H., Veihmeyer, F. J., and Nichols, P. F.: Canning quality of irrigated peaches, *Univ. Calif. Agr. Expt. Sta. Bull.* 479, 1929.

Hirst, F., and Adam, W. B.: The canning of solid pack apples, *Univ. Bristol Canning Expt. Sta. Misc. Pub.* 2, 1933.

——— and ———: Varieties of fruits for canning, *Univ. Bristol, Research Sta., Canners' Bull.* 3, May, 1931.

Hukill, W. V., and Smith, E.: Cold storage of apples and pears, *U.S. Dept. Agr. Circ.* 740, 1946.

Jones, O., and Jones, T. W.: "Canning Practice and Control," The Chemical Publishing Company, Inc., New York, 1937.

Kramer, A., and Haut, I. C.: Ripeness and color studies with raw and canned peaches, *Amer. Soc. Hort. Sci.*, **51**, 219–224, 1948.

Lamb, F.: Lighting in canneries, *Canning Trade*, May 10 and 17, 1954.

Leonard, S., Luh, B. S., and Foytik, J.: Cannery losses for cling peaches, 1954 season, *Univ. Calif. Agr. Expt. Sta. Rept.* 180, 1955. Mimeographed.

———, ———, and Hinreiner, Elly: Flavor evaluation of canned cling peaches, *Univ. Calif. Dept. Food Technol. Rept.*, 1955. Mimeographed.

———, ———, ———, and Simone, Marion: Maturity of Bartlett pears for canning, *Food Technol.*, **8**(10), 478–482, 1954.

Magness, J. R., Diehl, H. C., and Allen, F. W.: Investigations on handling Bartlett pears on Pacific Coast, *U.S. Dept. Agr. Tech. Bull.* 140, 1929.

Mechanization and automatic systems for materials handling for canning, *Western Canner and Packer*, **37**(2), 30–31, February, 1945.

Mrak, E. M., and Richert, P. H.: The swelling of canned prunes, *Univ. Calif. Agr. Expt. Sta. Bull.* 508, 1931.

National Canners Association Research Laboratories: Dietetic canned foods, Washington, D.C., 1953. See also Annual Reports.

Neubert, A. M., Veldhius, M. K., and Clore, W. J.: Effect of maturity on the canning quality of Western grown Elberta peaches, *Fruit Products J.*, **23**, 292–297, 315–317, 1944.

Oman, D.: Pineapple canning in war time, *Western Canner and Packer*, **37**(9), 54–57, September, 1945.

Philp, G., and Davis, L.: Peach and nectarine growing in California, *Univ. Calif. Agr. Ext. Serv. Circ.* 98, March, 1936 (revised April, 1946).

Pineapple (canning and growing), *Western Canner and Packer*, June, 1934, pp. 19–31.

Reed, H. M.: Improved methods of utilizing the magnolia fig, *Texas Agr. Expt. Sta. Bull.* 483, 1933.

Ruyle, E. H., Pearce, W. E. and Hays, G. L.: Prevention of mold in kettled blueberries in number 10 cans, *Food Research*, **11**(3), 274–280, 1946.

Schwartze, C. D., and Myhre, A. S.: Growing blueberries in the Puget Sound region of Washington, *Puget Sound Agr. Expt. Sta. Circ.* 245, 1954.

Smith, H. R.: The canning of freestone peaches in Georgia, *Canner*, **100**(4), 13–16, 26, Jan. 27, 1945.

Smock, R. M., and Neubert, A. M.: "Apples and Apple Products," Interscience Publishers, Inc., New York, 1950.

Strachan, C. C., Atkinson, F. E., Moyls, A. W., Kitson, J. A., and Britton, Dorothy: Canned pie fillings, *Can. Food Inds.*, November, 1954.

Streamlined fruit cocktail at Barron-Gray, *Western Canner and Packer*, **36**(12), 19–23, November, 1944.

Thurber, F. H., and Bohne, P. W.: Rotary lye peeler, *Food Inds.*, **18**(1), 78–80, January, 1946.

U.S. Department of Agriculture: Standards and specifications for canned apricots, figs, cherries, peaches, pears, pineapple, and other canned fruits. Obtainable from U.S. Department of Agriculture, Agricultural Marketing Administration. Specify the canned fruit for which U.S. grade specifications are desired.

Walsh, John S.: Better lighting, better work, *Food Inds.*, **18**, 1548–1550, 1676–1678, 1705–1707, 1830, 1946.

Waterman, M. N., and Associates: Lighting for canneries, *Illum. Eng.*, **45**, Jan. 11, 1950.

CHAPTER 9

PICKLING AND CANNING OF RIPE OLIVES

According to certain ancient writers, olives were pickled in a crude way in salt or were treated with wood ashes to remove the bitterness. Methods now in use are of comparatively recent origin. The present chapter covers only the pickling and canning of ripe olives. See Chapter 22 for pickling of Spanish green olives and other types of pickled olives.

Extent of Industry. The usual annual pack of canned ripe olives in California is about 2 million cases, the 1954 output being 2,056,000 cases and the 1956 pack 2,500,000 cases. The United States imports annually about 6 million gal. of green olives, equivalent to about 1,200,000 cases.

About 1900 Professor F. T. Bioletti, then at the University of California, and Mrs. Freda Ehmann, a commercial packer, independently discovered that ripe olives after a preliminary treatment to remove the bitter principle could be canned and preserved by heat in the same manner as other food products. The olive-pickling factories of the state were quick to realize the advantage of this method of preservation and to adopt it. At first the canners used 212°F. for processing. Later developments, viz., outbreaks of botulism, proved that this temperature is inadequate and unsafe. Present processing is at 240°F. for 60 min.

Varieties. The most important variety is the Mission, and over 50 per cent of the acreage is of this variety. The fruit is of medium size and oblong in shape with a pronounced point at the blossom end. It is rich in oil, of firm flesh, and of excellent pickling quality. It is not so large as the other varieties but is higher in oil content.

The Manzanillo olive is the second in importance. It is cherry-shaped and slightly larger and ripens about 2 weeks earlier than the Mission. For this reason it is preferred to the latter in districts subject to early frosts. It is used in Seville, Spain, for green pickling and is very popular as a stuffed green olive.

The Sevillano, or "Queen," olive is third in importance and is the variety grown in Spain for the preparation of the large Queen green olive. Most of the fruit is 1 in. or more in diameter, as compared with ¾ in. or less for the Mission. The Sevillano is very much more difficult to pickle than either the Mission or the Manzanillo. On account of its very large size, however, it is

in demand, and in certain districts of California the orchardists are grafting the Mission and Manzanillo trees with Sevillano scions. The Sevillano derives its name from Seville, where it is the most important variety used for green pickling. In Spain it is known as the Gordal.

The Ascolano variety is nearly as large as the Sevillano. After pickling it is crisp in texture and of pleasing flavor. It is a favorite in Italy, and derives its name from the town of Ascoli. In Italy it is known as "oliva bianca d'Ascoli." Many other varieties are grown in Europe.

Chemical Composition of Olives. Unpickled olives are intensely bitter. A number of chemists, principally Bourquelot, Vintellesco, Power, and Tutin, have investigated the chemical nature of the bitter principle. Power and Tutin believed that the bitterness is due to gums or tannin, while Bourquelot and Vintellesco contend that the bitter principle is a glucoside, to which they have given the name "oleuropein." The author obtained it in purified form in 1930 and studied its properties. It is a levorotatory glucoside, yielding α-d-glucose on acid hydrolysis. It reduces Fehling solution and on alkaline hydrolysis yields caffeic acid and a levorotatory complex, free of bitter taste.

The bitterness is destroyed by dilute alkali at room temperature, and neutralization of the excess alkali does not cause a return of the bitterness after it has been destroyed by the alkali. The bitterness can also be destroyed by treatment with dilute acid in an autoclave under pressure. The principal step in the pickling process consists in the destruction of the bitter principle with sodium hydroxide.

The flesh of ripe olives of the Mission variety contains from 20 to 25 per cent oil, that of Manzanillo olives about 16 to 18 per cent, and that of the Sevillano and Ascolano varieties less than 15 per cent.

In addition to oil, the fruit contains normally from 6 to 10 per cent of soluble solids, of which mannite is one of the most important constituents. The juice of the Mission olive is acid in reaction and, when titrated with one-tenth normal alkali, is equal in acidity to a 0.4 to 0.5 per cent citric acid solution. It is probable, however, that the acids in the olive are complex in nature and are not so simple as citric, malic, or tartaric acid.

In the pickling process most of the soluble compounds are removed by leaching. Olive oil remains in the pickled product as the principal constituent of the flesh, the remainder being mainly crude fiber.

Cruess, El Saifi, and Develter (1939) found that ripe Mission-variety olives contained before pickling water 56.3 per cent, water-soluble solids 13.1 per cent, oil 24.4 per cent, total sugars 4.6 per cent, protein 1.65 per cent, mannite, 4.4 per cent, and alcohol precipitable 0.47 per cent; while the pickled olives of the same lot contained water 63.4 per cent, water-soluble solids 6.5 per cent, oil 26.4 per cent, total sugars 0.10 per cent, protein 1.56 per cent, mannite 0.94 per cent, and alcohol precipitable 0.43 per cent.

Picking. For ripe pickling, Mission and Manzanillo olives are at the optimum stage of maturity when the color of the fruit has become cherry red to straw yellow. Fruit that has arrived at the jet-black stage is apt to soften in the pickling process, and that which is green in color yields a tough pickled product of poor flavor. Sevillano and Ascolano olives are picked at a less mature stage, since they soften severely during pickling if the fruit shows much color when picked.

R. W. Hilts, former director of the Pure Food and Drug Laboratory of the U.S.D.A. in San Francisco, has made a tentative recommendation that the flesh of the Mission olive shall contain at least 17 per cent oil and that of the Manzanillo at least 15 per cent oil if the pickled product is labeled "ripe." He has made no recommendation for the Sevillano and Ascolano varieties. If the fruit has reached the cherry-red stage of maturity it will, in most cases, conform to the minimum standards suggested by Hilts. A similar study made more recently by Pitman indicates that the recommendations made by Hilts are very reasonable.

The unpickled olives are extremely sensitive to bruising, and therefore great care must be exercised in picking the fruit and transporting it to the factory. Buckets made of canvas are commonly used in picking, and the buckets of fruit are emptied into shallow lug boxes fitted with cleats to protect the olives against bruising when the boxes are stacked. Several pickings must be made since the fruit does not all ripen at one time.

In the early districts in California the picking season begins about Oct. 1 and in favorable seasons may last until Dec. 1.

Holding Solutions. Most factories do not possess a sufficient number of vats to care for all the fruit as rapidly as it arrives. It is therefore necessary to store a considerable proportion of the crop in dilute brine until the pickling vats become available. A hydrometer known as a "salometer" is employed in testing the strength of the brine. A 3 per cent solution is equal to about 12° salometer, and 10 per cent equal to about 40° salometer (see Table 48).

Large wooden or concrete tanks are used for storage. If these are indoors, molds and film yeasts are apt to grow on the surface of the brine and may reduce the acidity of the brine to the point where spoilage can occur or may secrete enzymes that cause softening of the olives. Most olive-storage tanks, therefore, are located outdoors where the sunlight prevents the growth of most film-forming organisms.

A layer of brine is usually placed in the bottom of the tank to prevent undue bruising of the olives as the tank is being filled. In most plants the olives are transported from the lug boxes to the storage tanks by pumping in brine or by fluming in brine or in water. In smaller plants they may be dumped by hand from the lug boxes.

The initial brine is usually 20 to 30° salometer, but for the Ascolano

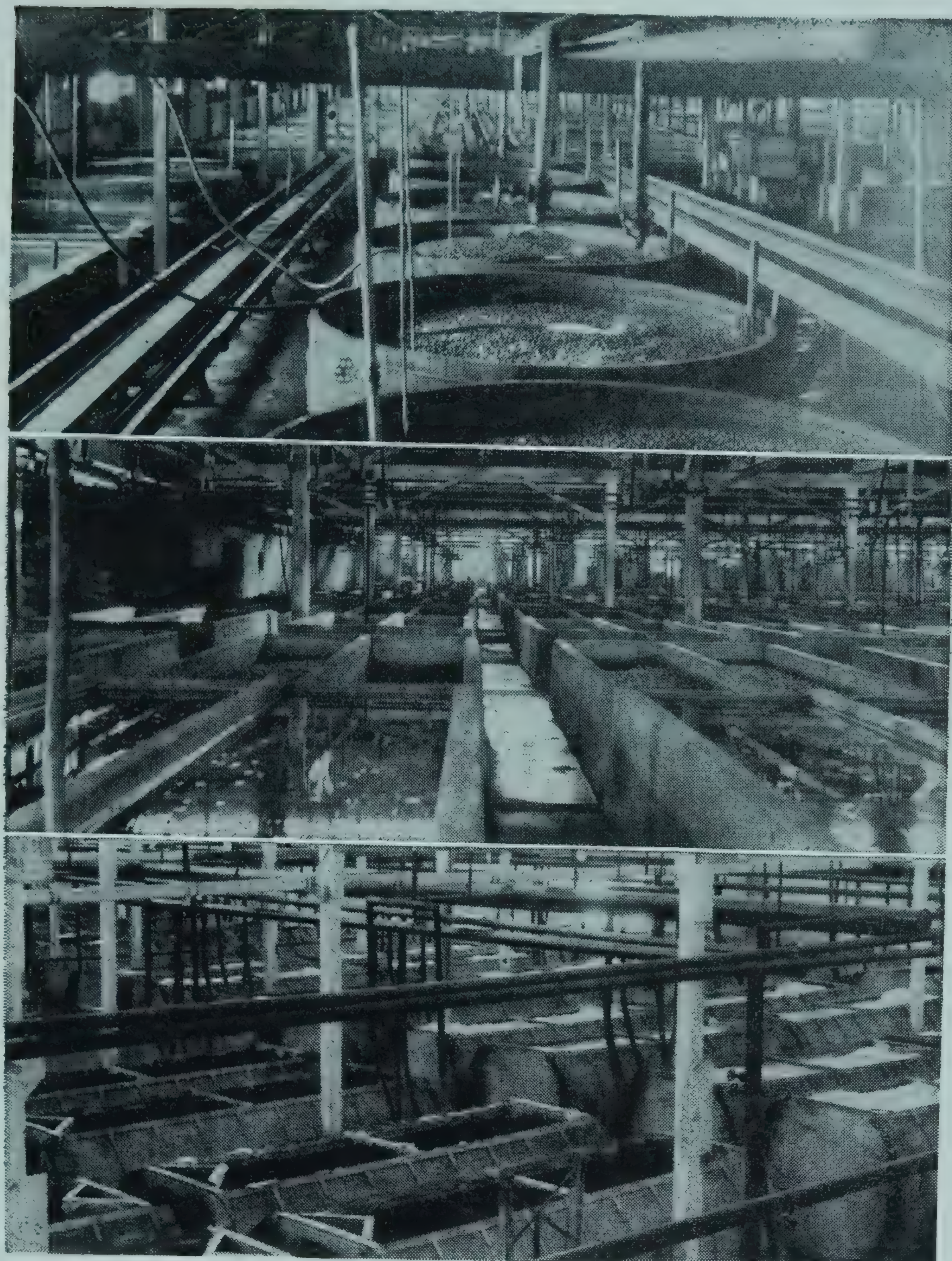


FIG. 42. Ripe-olive pickling vats. *Top:* Circular redwood vats. *Center:* Concrete vats. *Lower:* Cylindrical wooden vats equipped with compressed air.

variety it may be as low as 15° salometer because it shrivels badly in strong brine. At intervals of one to several days the salometer degree of the brine is taken by hydrometer and half-ground salt or saturated brine is added to increase the salometer degree slightly until it remains constant at 30 to 36° salometer for about the first 3 months of storage. It is then increased slowly for Mission and Manzanillo varieties as the weather becomes warmer to about 40° salometer. If the brine is to be held during the summer, it may be increased to as high as 50° salometer. For the Sevillano variety the final salometer degree is seldom above 30 to 32° salometer.

The tanks are covered, i.e., headed, and the brine stands to a depth of several inches on the head, which has openings to allow circulation by pump when salt or saturated brine is added. It is customary in most plants

to maintain a supply of saturated brine formed by filling a tank nearly full of half-ground rock salt and adding water to cover. Saturated brine is drawn off from the bottom of the tank at 100° salometer.

Fermentation in Holding Solution. In solutions containing less than 8 per cent salt (32° salometer) fermentation in warm weather is fairly rapid. Usually a lactic acid concentration of 0.4 per cent is attained. It acts as a mild antiseptic, preventing the growth of putrefactive bacteria, but not the growth of molds and yeasts. In cold weather fermentation becomes slow or may cease.

Deterioration in Holding Solution. If the olives are placed directly in a 10 per cent salt solution, they are apt to shrivel badly. It is therefore necessary, as stated previously, to increase the concentration of the brine progressively by small additions of salt from day to day. This is particularly true of Sevillano and Ascolano olives.

If bacterial growth is very pronounced, the olives become bleached in color, apparently by a reducing action, because the color can be returned to the fruit by oxidation. If the salt concentration is too low or the acidity insufficient, bacterial softening is very apt to occur, owing to action of bacteria of the *Bacillus coli* and *Aerobacter aerogenes* group. At the first sign of such spoilage the brine should be acidified with 0.5 per cent lactic or 0.25 per cent acetic acid or the olives pickled at once. Gas blisters often form in such spoilage and are responsible for the term "fisheye spoilage."

Storage for 6 weeks or longer in holding solution appears to be desirable if its optimum effect is to be obtained. The length of time that olives may be held in satisfactory condition in a holding solution varies according to the variety of the fruit, the storage temperature, and the concentration of the brine. Olives of the Mission variety have been held for 18 months in a strong brine solution without appreciable deterioration in quality.

Occasionally olives in brine storage become soft at the stem end, a condition caused by pectic enzymes secreted by molds or bacteria. If such spoilage occurs, the olives should be pasteurized at 140 to 150°F., cooled, and then pickled at once.

Another undesirable condition is known as "nailhead" deterioration, characterized by small depressions formed beneath the skin and ranging in diameter from about ½ to 1½ mm. These depressions persist in the pickled product. It is probably caused by bacterial action, as colonies of bacteria are found in the depressions. Delay in placing the olives in storage after picking and rough handling after arrival at the plant appears to aggravate this condition, according to Vaughn and Webster.[1] It can be avoided, of course, by pickling the olives directly after picking, but in most plants this is not feasible. At present no means of completely preventing this form of spoilage during brine storage of unpickled olives is known.

[1] Personal communication, 1955.

Occasionally in warm weather, if the storage brine is not sufficiently high in salt content, spoilage by *Aerobacter* or related bacteria may occur with softening of the olives and formation of gas pockets in the flesh, a type of spoilage known in the industry as "fisheye" spoilage. If it should appear, the brine should be built up by addition of salt or saturated brine and the brine acidified with about 0.5 per cent of lactic or acetic acid to inhibit the growth of the spoilage bacteria; or the olives should be pickled at once. See further discussion of this form of spoilage later in this chapter.

Grading before Pickling. In most factories the fresh olives are graded for size before they are placed in holding brine, usually with a grader that consists of moving diverging steel cables similar in design and operation to orange graders. Cherry graders have been employed, but because of the oblong shape of most olives, the screens with circular openings do not give satisfactory separation of the olives. The roller grader used for oranges has been successfully modified in size and design to make it suitable for the grading of olives. The most popular grader at present is the Sammis diverging-cable grader or other grader using the diverging-cable principle. It is accurate and has a large capacity.

The unit for designation of the different-size grades is $\frac{1}{16}$ in., the largest being $\frac{17}{16}$ in. in diameter and the smallest size normally used for pickling $\frac{10}{16}$ in. in diameter. Olives smaller than this are used for oil, olive mince, etc. (Chapter 4).

It is desirable to grade the olives for size before pickling so that the action of the lye may be uniform. It requires a much shorter time for the lye to penetrate the flesh of small than of large olives, and for this reason if the small and large fruit are pickled in the same vat, the small fruit will be softened and bleached by excessive lye action or the large fruit will remain bitter. In addition to grading the fruit for size, it is customary in some factories to sort it carefully for color into two or three grades—black, cherry-red, and green fruit. Overripe fruit is more subject to injury by lye action than the green fruit. On this account the sorting of the fruit into grades representing the three degrees of maturity is desirable (see also Chapter 4 for size grades for ripe olives).

Pickling Vats. Olives are pickled in shallow vats, usually constructed of concrete. These are generally about 8 by $2\frac{1}{2}$ ft. and about $2\frac{1}{2}$ ft. in depth. Circular or rectangular redwood tanks are also used, but concrete vats are less liable to become moldy or infected with bacteria and are more easily cleaned. The wooden tanks, however, are portable, and their use makes it possible to utilize the floor space in the pickling room for other purposes after the pickling season is completed.

Another vat is cylindrical in shape and with an opening about 2 ft. wide extending the full length of the top. Air for stirring and aerating is distributed by perforated pipes in the bottom of the vat. This vat was developed

by the Lindsay Ripe Olive Co. In most factories the vats are supplied with three overhead pipelines, one containing water, one dilute lye solution, and one dilute brine. In most factories a fourth pipeline conveys compressed air to the vats. The vats are equipped with outlets for discharge of spent lye, brine, or wash water into open floor drains.

Initial Lye Treatment. During the pickling process the olives are subjected to several applications of dilute sodium hydroxide (lye) solutions. The first few applications, usually three to five, are for the purpose of developing color in the skin or in the flesh immediately beneath the skin of the olive. The concentration of NaOH in the first lye application ranges from about 2 per cent to as low as 1 per cent, depending upon the variety of olives, length of storage in brine before pickling (the longer the storage period the lower the concentration of lye), and the temperature of the water. Even more important is the fact that the different plants have different lye-treatment schedules, including different concentrations of NaOH, different total number of lye applications, and different temperatures. One plant, for example, uses lye solutions of 1.2 per cent NaOH for all of its applications; another's schedule is 1.85, 1.5, 1.25, and 0.75 per cent NaOH, four lye applications in all; in another plant the solutions used were 2, 2, 1.2, 1.2, and 1.2 per cent, a total of five applications. In still another plant eight lye applications were used, during a recent season. In general, the greater the number of lye applications and the shorter the period of each treatment the better the color will be. The trade desires a uniform black color. This is obtained by oxidation of phenolic compounds naturally occurring in the olive or formed by action of the lye on complex substances of the fruit, such as the bitter principle, oleuropein. The pickler's principal responsibility is to obtain such a color by proper lye treatments and oxidation of color bases in the olive by exposure to air or aeration of the olives in water between lye treatments.

Duration. In some factories the first lye is allowed to remain on the olives until it has penetrated the entire skin of the fruit but not long enough to penetrate more than $\frac{1}{16}$ in. into the flesh. In most plants the first lye solution is allowed to penetrate about one-fourth of the olive skins. In other plants the first three or four lyes are allowed to remain on the olives only a short time and to barely penetrate the skins of all the olives, three or more lye treatments being required. The olives are exposed or aerated in water for several hours between lye treatments. This aeration usually produces a good color. Additional lye treatment is necessary in order to destroy the bitterness.

Temperature. The rate of lye penetration is more rapid at higher temperatures, the preferred range being 50 to 70°F. Where it is less than 50°F. it is advisable, usually, to warm it to 60 to 65°F. for use in lye solutions. Some picklers use a more dilute lye solution, for example, $\frac{1}{2}$ to $\frac{3}{4}$ per cent, and

allow it to remain on the olives a longer time. Experience demonstrates, however, that the stronger lye solutions penetrate the olives more uniformly than do the very dilute solutions, particularly if applied for short periods with exposure to air or aeration in water between lyes. The principal objection to strong lye solutions is that they may cause bleaching of the color of the olives if left on the fruit too long.

Darkening of the Color. The progress of the lye penetration can be followed by placing a drop of dilute phenolphthalein solution on the cut surfaces of the olives or by noting the discoloration of the skin and flesh caused by the lye. In one common technique of olive pickling, after the skin of the entire fruit has been well penetrated, the lye is removed and the fruit is exposed in the vats until it is black or dark brown. Preliminary investigations indicate that the olive contains tannins of the catechol group and that the darkening process is probably very similar to the darkening of pyrogallol in dilute alkalies.

The usual total length of the various exposures is 3 to 5 days. During this exposure to the air the olives must be stirred three or four times daily in order that the darkening may be uniform. If this is not done, air is excluded from the surface of the olives at points of contact between the individual fruits, and this area remains lighter in color than the fully exposed surface, resulting in a spotted or mottled appearance. The usual method of stirring the olives is to cover them with water and to agitate the liquid with compressed air for 2 or 3 min. Or the olives may be covered with water and stirred by means of a wooden paddle. The compressed air is less liable to cause bruising (Figure 42).

Aeration under Water. In several large factories the olives are not exposed to the air following the first lye process but are covered with water, which is thoroughly aerated by means of compressed air delivered to the vats through perforated pipes placed in the bottoms of the vats (Figure 42). The oxygen of the air dissolves in the water to a sufficient concentration to cause darkening of the fruit.

The flesh of the olives darkened by the aerated-water process is generally lighter in color than that of olives darkened by exposure to the air. A pickled olive of light-colored flesh and dark skin is considered superior to one of dark skin and dark flesh.

Final Lye Treatment. In most commercial olive-pickling plants the olives receive four or five or more treatments in dilute lye after the first lye treatment and exposure. Regardless of the number of lye solutions employed, the last lye solution is used for the purpose of destroying the bitter principle. Therefore it is customary to allow this last lye solution to penetrate to the pit of the fruit. If it consists of 0.75 to 1 per cent sodium hydroxide, it will generally remove all trace of bitterness if allowed to penetrate completely to the pit.

The lye penetrates most rapidly at the stem end of the fruit, and hence it frequently happens that the blossom end of the fruit will remain bitter, while the stem end will be free from bitterness. If the lye action is too prolonged, the stem end of the fruit may become bleached in color. It is therefore necessary to note carefully the depth and rate of lye penetration in order that the quality of the fruit may not be injured and that all the bitterness may be removed.

It is not possible to give the length of lye applications within narrow limits. In most cases if the final solution is of low NaOH content it is allowed to remain on the olives overnight. A more concentrated solution may complete its action in 8 to 10 hr. or less.

In any event, the final lye solution is allowed to penetrate completely to the pits in order to destroy all the bitterness and to "cure" the flesh.

Removal of Lye. Following the last lye treatment the olives are leached with water until they no longer contain either sodium hydroxide or bitterness. The water is changed frequently, at least twice daily, and is stirred frequently by means of paddles or compressed air. It usually requires from 5 to 7 days' treatment to remove all the lye from the fruit. If, however, the olives are stirred continuously with compressed air, it is possible to leach the lye from the fruit in much less time.

Effect of Temperature. Water at 75°F. will remove the lye approximately twice as rapidly as water at 60°F. Although the higher temperatures cause more rapid solution of the lye from the fruit, their use is not advisable for the reason that the growth of bacteria is favored; very frequently fermentation and softening of the fruit occur in factories in which the temperature of the wash water is above 70°F. In several plants the water is replaced with brine of 10 to 12° salometer after about 3 days' leaching in water. Also it is often heated to 160°F. or above to hasten lye extraction.

In experiments conducted by the author and Perry (1953) it was found that the application of dilute HCl or other mineral acid after 2 or 3 days' washing in water greatly increased the rate and completeness of removal of NaOH from the olive tissues. An 0.05 per cent solution of HCl for two periods of 6 hr. each or a 0.01 per cent solution for longer periods proved satisfactory in the experiments. If too strong a solution is used, the color of the olives will be bleached. Dilute sulfuric acid can be used instead of HCl.

Recovery of Spent Lye Solutions. In most olive factories the lye solutions after removal from the olives flow to a central tank, where they are titrated and sufficient lye is added to bring them to the desired strength. They may be used in this manner three or four times.

Spoilage and Pasteurization. At 70 to 75°F., "floating," fermentation, and softening may be very rapid and cause severe losses. Experiments made by the author in 1921 and 1922 have demonstrated that such spoilage of the olives can be checked by heating to 175°F. for 30 min., should any

evidence of fermentation occur. The heating must be done very carefully in order that the flesh of the olives shall not be broken by contact with jets of steam or by too violent agitation. The most convenient means of heating the water is by a portable steam siphon placed above the vat. Another method of heating the olives in the factory consists in drawing off the water from the vat, heating it to the boiling point, and returning it to the olives until the desired temperature is obtained. One heating of this sort is usually sufficient to check fermentation and softening.

In addition to the fermentation and softening effects, the bacteria injure the flavor and exert a reducing action, evidenced by the fact that the color of the olives becomes bleached and will reappear if they are given a light lye treatment and are then exposed or aerated. In severe cases fisheye-like blisters are formed beneath the skin, giving the name of "fisheye spoilage" to this form of deterioration. Research by Tracy of the University of California showed the organisms to be of the *Bacillus coli* and *Aerobacter* groups. Vaughn, also of the University of California, has greatly extended Tracy's studies.

The progress of the washing process can be determined by applying a dilute solution of phenolphthalein to the cut surface of the olives, a 1 per cent solution of this indicator in 95 per cent alcohol being satisfactory for the purpose. The taste of the operator is, however, a more delicate indicator of the presence of lye than is the phenolphthalein. Phenol red is a much better indicator, as pH can be judged by its use. Investigations by the author have shown that the color of the olives sometimes bleaches during retorting in the cans at 240°F., if the pH value exceeds 8.0, and that the color is most permanent if the olives are washed until the pH value is about 7.5. This point can be determined by use of phenol-red indicator applied to the cut surface or by glass electrode placed in the expressed juice.

Needle Board. If the olives are inclined to shrivel during brine curing toward the end of the pickling process, they are often passed over a needle board to puncture the skins. Schutt (1952) has described one that has been in use in his plant for many years. It consists of a stainless-steel pan 17 in. wide by 36 in. long, studded with sharp pins. The pan is tilted at an angle and is vibrated rapidly by electric motor.

Olives are fed from a hopper above the upper end of the pan. They bounce down over the pins, which puncture the skins in numerous places. The "throw" of the pan is $\frac{3}{32}$ in.; its capacity is 3 tons per hour. The brass pins are No. 17 size and are soldered into holes in the pan on $\frac{1}{2}$-in. centers. They project $\frac{1}{16}$ in. above the floor of the pan.

The punctured olives "take" the brine more readily and with less shrivel than occurs with the untreated olives.

A sheet of plastic of sufficient thickness to hold the "needles" and provide sufficient rigidity has been used successfully as a needle board. It has the

great advantage that the metal pins are easily inserted and soldering is avoided.

Curing in Dilute Brine. After all the lye has been removed from the fruit, it is stored in a brine of about 2 to 2½ per cent salt (8 to 10° salometer) for about 2 days. Storage of the fruit for a longer period is dangerous, because softening, fermentation, and other bacterial troubles may arise. In several plants, as previously stated, the olives after washing in water for several days are placed in brine of 10 to 12° salometer, changed several times daily. It impregnates the olives with a pleasing amount of salt and is thought to check loss of color. In some plants the olives are heated to 160°F. or higher in the brine in order to hasten leaching of the last traces of NaOH and prevent bacterial spoilage.

Sorting and Grading. The pickled fruit is passed over broad, flat belts and is carefully sorted and graded for color and quality. The bitter fruit, which can be recognized by its mottled color at the blossom end, is removed and returned to the pickling vats. The well-pickled fruit is usually graded to two or three degrees of color, viz., light brown, dark brown, and black. It is also sometimes graded again for size, because during the pickling shriveled fruit becomes plump and increases in size and other changes in size take place.

The broken and soft fruit is sorted out and sent to the oil mill (see Chapter 4 for size grades of olives).

Canning. The cans now used, as a result of experiments at the University of California, are lined with a protective enamel, in order to prevent bleaching of the color after canning. The sizes used most commonly are Tall Pints, Buffet (211 × 304), Picnic (211 × 400), the 211 × 414, No. 10, and No. 1 Tall cans. For chopped olives and the sliced, 4-oz. cans are used.

The olives should be heated in water a short time before they are placed on the canning tables so that the women who fill the cans may handle the fruit conveniently, as canning normally occurs during the cold winter months.

The cans are filled by weight in much the same manner as other fruits. This is usually done by hand-pack filler (Figure 38). Formerly brine was added by machine to fill the cans, but common practice at present is to fill the cans with very hot water and then add to each can the required amount of dry salt by automatic dispenser as the can travels from the filling station to the double seamer; or the salt may be added before the hot water.

Exhausting and Processing. Formerly the filled and brined cans were heated in an exhaust box at 200 to 205°F. for about 5 min. before sealing. A more common practice is to add hot brine to fill the cans and then seal in the usual manner or in steam, in either case without heating in an exhaust box. A variation of this procedure is to add salt from the dispenser and fill the cans with hot water, as previously outlined.

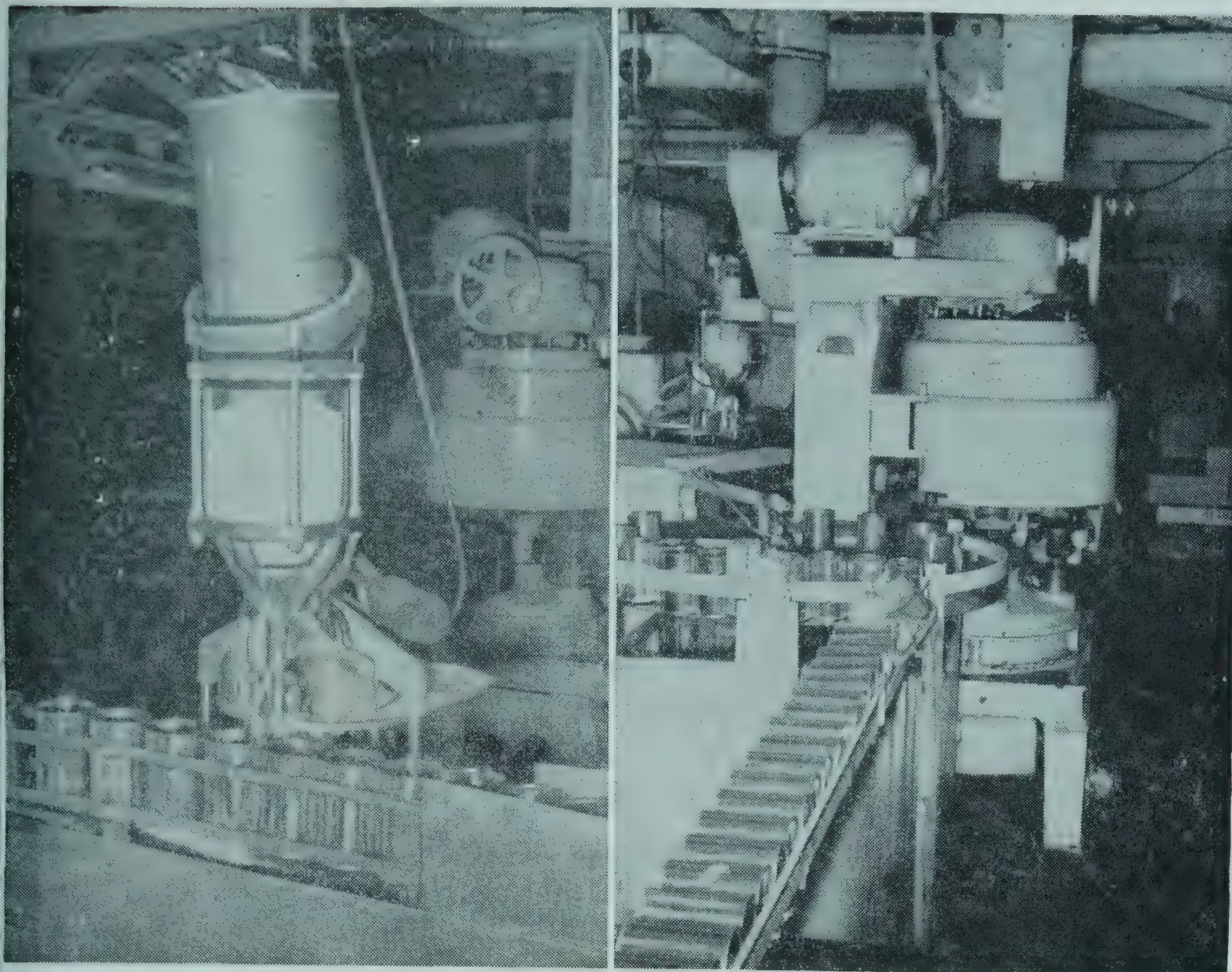


FIG. 43. *Left:* Salt dispenser. Adds measured volume of salt to each can. *Right:* Double seamer for cans. (*Rocca Bella Olive Association, Wallace, Calif.*)

The canned olives are processed and sterilized at 240°F. for 60 min. under California State Board of Health inspection. The Board requires that a temperature-chart record of every retort load of canned olives be made and submitted to the inspection service. Also the cans or jars of each retort load must be given an identifying code mark so that if there is any question concerning the temperature-chart record or other point the cans or jars may be set aside and resterilized or given such other treatment as the Board may require.

If the olives are packed in glass containers they must be sterilized in water in a retort with superimposed air pressure, as described in the chapter on the sterilization of canned and glass-packed foods. The air pressure is necessary in order to prevent the pressure that develops in the jar during processing, forcing the lids off the jars. The California State Board of Health has established definite procedures that must be followed in the retorting of olives in glass in either vertical or horizontal retorts. In one large plant the smaller cans are processed in a continuous agitating retort at 262°F. for 25.2 min.

Pitted Olives. Some ripe olives are pitted by automatic pitters, such as the Ashlock pitter or Lindsay Ripe Olive Company olive pitter. They are

then canned in the same manner as the unpitted olives for table use and for use in cooking. Pitted olives have greatly increased in popularity and now constitute a large proportion of the pack. Pitted olives were first canned by the Lindsay Ripe Olive Company, which also developed the first successful olive-pitting machine. Some pitted olives are cut in rings and canned.

OTHER CANNED OLIVE PRODUCTS

A product of rapidly increasing popularity is canned "home-process" olives, otherwise known as "green-ripe" olives and by other names. Ripe olives of the Manzanillo, Sevillano, or Mission varieties (pink or yellow but not black in color) are treated with several successive lye treatments until the lye reaches the pits. In experiments in the University of California Food Technology Department laboratory three lye solutions were employed, the first being 1.5 to 1.65 per cent sodium hydroxide, the second 0.75 per cent, and the third 0.5 per cent. The olives are not permitted to darken between lye treatments. Two lye applications are generally used commercially, the concentration being somewhat higher than in our experiments. This product was first packed commercially by the Adams Olive Co. The lye is removed by soaking the fruit in water changed several times daily, as described for ripe olives. The olives are then stored in dilute brine 2 or 3 days and are canned as previously described for the usual process.

Green olives are also prepared and canned in this same manner. The canned product should be golden yellow in color. Olives of this type are sometimes known as "California Canned Green Olives."

Since it is difficult to remove the last traces of lye from the tissues of olives pickled in this manner, some packers add dilute acid to the water applied to the olives from which some of the lye has been leached. In tests at the University of California a solution of 0.25 per cent hydrochloric acid was applied until neutralized by the residual lye in the olives. Washing was then continued in the usual manner until near the end of the washing period, when sufficient 100-grain vinegar was added to reduce the pH value of the wash water to about 5.0. The last trace of lye can be removed also by pasteurization of the olives in water.

For preparing chopped olives the fruit is first pickled by the ripe process, the smaller sizes of olives being used. The pickled olives are pitted by the Elliott pitter, which cuts the flesh off the pits in strips. The strips are cut into small pieces in a two-stage slicing machine.

The "chopped" olives are heated in a continuous, steam-jacketed, screw conveyer and delivered at about 130°F. to a can-filling hopper. If heated much above this temperature, juice and oil are forced from the fruit, giving a "messy" canned product. The cans are filled by machine and sealed in steam (steam-flow or steam-vac seaming).

Cans of 4-oz. size are processed for 70 min. at 240°F.; a longer period is required for larger cans. However, most of the pack is in cans of 4-oz. size. As chopped olives conduct heat slowly, a longer process is necessary than for whole olives.

Canned chopped olives are popular for use in sandwiches and salads and are also used in various cooked dishes such as rice, spaghetti, stews, etc., or with steaks as a substitute for mushrooms and as an ingredient in stuffings used for turkey or other fowl.

Color Retention. The desirable dark brown to black color formed by oxidation during pickling may be lost in any one of several ways. If the lye applications are too severe, or the wash water is very soft, color may be lost by leaching; if incipient bacterial spoilage occurs during washing, the color may be lessened; and if the olives are canned at too high a pH value or washed to too low a pH value, color may be lost during retorting. In plain tin cans the color bleaches during storage after canning, but is well retained in enamel-lined cans and in glass containers.

Treatment with dilute acid during the final stages of washing tends to retain color by shortening the washing period and by reducing the pH value of the olives to the point at which less color is leached from the fruit by the wash water. In experiments conducted by the author and graduate students under his direction it was found that treatment of the olives for about 24 hr. with 0.25 to 0.50 per cent $CaCl_2$ after the final lye treatment tended to fix or set the black color so that much less was lost during subsequent washing to remove lye. The $CaCl_2$ was leached from the fruit during the washing period and by final pasteurization at 175°F. However, if it is not reduced to a very low concentration by leaching with water, it will impart a brackish taste to the canned olives during retorting.

Application of brine for several days after the olives have been washed for about 3 days following final lye treatment tends to fix the black color, as does also the usual pasteurization in brine. The brine is used during the final stages of washing to leach the last traces of lye from the fruit as well as to impregnate the olives with salt and to retain color.

Green Spanish-style Olives. The Spanish process of preparing green olives is described in Chapter 22.

REFERENCES

Ball, C. O.: Processing foods for sterilization, *Food Inds.*, **19**, 44–46, 138, 174–178, 282, 286, 338–340, 432, 1947. Covers glass containers.

Ball, R. N.: Off flavors in olives resulting from processing (pickling), *Proc. Calif. Olive Assoc. Tech. Conf.*, 1953, pp. 33–35.

Bioletti, F. T.: Size grades for ripe olives, *Univ. Calif. Expt. Sta. Bull.* 263, 1916.

Cruess, W. V.: Factors affecting the stability of color of canned ripe olives, *Food Technol.*, **6**(3), 110–113, 1952.

CRUESS, W. V.: Observations on shriveling of ripe olives, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1952, pp. 78–81.

———: The role of enzymes in olive pickling, *Fruit Products J.*, **27**(2), 44–46, 1947.

———: Olive products, *Ind. Eng. Chem.*, **33**, 300–304, March, 1941.

———: Effect of pH value on stability of color of canned olives, *Proc. Olive Assoc. Tech. Conf.*, 1929, pp. 35–45.

———: Factors affecting the sterilization of olives, *Univ. Calif. Agr. Expt. Sta. Bull.* 333, 1921.

——— and ALSBERG, C. L.: The bitter glucoside of the olive, *J. Am. Chem. Soc.*, **56**, 2115–2117, 1934.

———, EL SAIFI, A., and DEVELTER, E.: Changes in olive composition during processing, *Ind. Eng. Chem.*, **31**, 1012–1014, August, 1939.

——— and GUTHIER, E. H.: Bacterial decomposition of olives during pickling, *Univ. Calif. Agr. Expt. Sta. Bull.* 368, July, 1923.

———, KOBAYASHI, G., and MEYERS, E.: Color retention studies with ripe olives, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1952, pp. 88–91.

——— and PERRY, W.: Further observations on retention of color in ripe olives, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1953, pp. 73–79.

GILILLAND, R., and VAUGHN, R. H.: Characteristics of butyric bacteria from olives, *J. Bacteriol.*, **46**(4), 315–322, 1943.

HILTS, R. W., and HOLLINGSHEAD, R. S.: A chemical study of the ripening and pickling of California olives, *U.S. Dept. Agr. Bull.* 803, 1920.

KAWATOMARI, T., and VAUGHN, R. H.: Species of Clostridium associated with zapatera spoilage of olives, *Food Research*, **21**(4), 481–491, July–August, 1956.

KINMAN, C. F.: Olive growing in the southwestern United States, *U.S. Dept. Agr. Farmers' Bull.* 1249, 1922.

PITMAN, G. A.: Oil content as a criterion of maturity of olives, *J. Assoc. Offic. Agr. Chemists*, August, 1935, pp. 441–454.

POMEROY, D., and CRUESS, W. V.: Greek olive investigations, *Fruit Products J.*, **16**, 11–13, 22, 27, 43, 44, 59, September–October, 1936.

Proceedings of the Annual Olive Association Technical Conference, 1920 to 1957. Contain many papers on olive pickling. On file at University of California and at Olive Association, San Francisco. Not for sale.

SCHUTT, H. G.: Needle boards, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1952, p. 85.

SOMERS, I. I.: Laboratory examination of olive samples, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1952, pp. 32–36. See also *Proceedings* for other years.

STERLING, G.: Texture changes during the dark-ripe processing of olives, *Food Research*, **21**(1), 93–103, January, 1956.

VAUGHN, R. H.: The pectolytic activity of the Genus Bacillus and their relation to the softening of olives and pickles, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1952, pp. 67–69.

WEBSTER, J. R.: Operation olive, *Food Inds.*, **21**, 1557–1561, 1949.

WHITE, D., and LAMB, F. C.: Off flavors in olives resulting from field application of pesticides, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1953, pp. 29, 33.

CHAPTER 10

CANNING OF VEGETABLES

The annual output of canned vegetables in the United States is about 1½ times that of canned fruits. Peas, corn, and tomatoes are the most important of the canned vegetables.

General Comparison of Fruits and Vegetables. In general, we may consider canned vegetables as staple foods and the higher grades of canned fruits as dessert products. Vegetables differ from fruits in chemical composition, and for this reason the processes of canning differ from those used for fruits. Most vegetables contain more starch than sugar, as contrasted with fruits, which are high in sugar and low in starch.

The acidity of vegetables is generally much lower than that of fruits. Vegetables are grown in or near the ground as contrasted with fruits, which are grown generally on trees at a considerable distance from the soil. Vegetables, therefore, usually contain more of the resistant soil organisms than fruits and usually require more cooking than fruits to develop their most desirable flavor and texture.

For these reasons vegetables in general require a more severe processing than fruits in order to render them sterile and to cook them sufficiently for table use. Vegetables often contain disagreeable flavors, or compounds, which should be removed before canning, or some must be wilted by heating before canning, and for these reasons they are usually blanched before being filled into the cans. This process is not necessary with most fruits.

Vegetables are grown as annual field crops. Thus it is possible for the canner to contract for each year's supply of corn, peas, or tomatoes in the current year, and to a very large degree he can plan to control the amount of his seasonal pack.

Raw Products. The demands of the canner have developed the varieties of vegetables most suitable for canning purposes. In general, vegetables for canning purposes should be uniform in color and quality, tender, and in prime condition. Because of the rapid deterioration of vegetables after gathering, they should be transported from the field to the cannery in as short a time as possible, and for this reason the cannery should be located in or near the fields in which the vegetables are produced. This is particularly true of such quickly perishable vegetables as corn, tomatoes, spinach, and asparagus.

The cannery should arrange to plant the fields near the cannery in proper sequence, so that the produce will be delivered at a uniform rate over a long season.

Many canneries furnish the seed, or in some cases the small plants, to the growers so that they may be certain of obtaining the proper varieties for canning purposes. This is particularly desirable with tomatoes, peas, and corn.

ARTICHOKE[1]

(Cynara scolymus)

The artichoke that is canned in California is a member of the thistle family and is probably a native of southern Europe. The large flower buds resemble a green pine cone in appearance, and the fleshy bases of its scales, or "leaves," and the receptacle, or base, form the edible portion. The plants are grown in the cool, foggy area on and near the Pacific Coast in central California. The principal harvesting season is in the winter and early spring months. Most of the crop goes to the fresh market, but some is canned, and at present a small proportion is frozen.

At the cannery the artichokes are first graded for size by means of a pair of traveling, diverging endless ropes. The smallest "chokes" are taken out first, and the largest last. The smaller artichokes are used for canning, the largest size for this purpose being less than 2½ in. in diameter, as the largest over-mature specimens become fibrous. However, the smallest buds, too small for canning, are used for packing in flavored vinegar in glass, as described later in this section.

In the California Production Division of the Dole Hawaiian Pineapple Company, the size-graded artichokes are fed by hand into a machine built by the company that first cuts off the stem end and top of each artichoke and then, by means of a rapidly revolving crescent-shaped knife, trims the stem end to a rounded contour. The loss in trimming and shaping is about 75 per cent. The trimmed buds then pass through a small revolving rod reel, or "squirrel cage," under a water spray to remove loose "leaves" (scales) and small pieces of trimmings. They are then placed in a basket, and the basket is immersed in a citric acid solution of about 1.25 per cent acidity in a stainless-steel cylindrical tank and subjected to a high vacuum for about 30 sec. This treatment, a Hawaiian Pineapple Co. patented process, is called "blanching," although no heat is applied. The trimmed buds are impregnated with the dilute acid solution, which removes much of the air from the tissues. The blanched buds are then washed in a large

[1] The author is greatly indebted to Robert Quirk, director of research of the Dole Hawaiian Pineapple Co., of San Jose, California, for much of the information presented in this chapter on the canning of artichokes.

cylindrical, revolving squirrel-cage screen to remove loose leaves and trash.

Next they are sorted and graded into two or three size grades by hand from a slowly moving belt. They are then canned from stainless-steel sinks, and as they are canned three size grades, Medium, Small, and Tiny, are made by the canners. The can bodies are of plain 1.25 lb. per base box tin plate for the inside coating and 0.25 lb. per base box outside coating. The ends are enameled, as plain tin-plate ends may discolor slightly above the water line during processing.

The cans are filled in a prevacuumizing briner under vacuum with a brine containing about 0.35 per cent citric acid and 0.6 per cent salt. They are sealed in a vacuum-closing machine and processed in open retorts in boiling water for 30 min. and cooled to 100 to 110°F. in water.

The pH value after canning and processing is 4.2 to 4.3; i.e., it is about that of canned tomatoes. This acidity or rather low pH is essential in a product processed at 200 to 212°F. and is desirable in a product used on the table as an appetizer or in salads. Also, if the artichokes are not acidified, they must be retorted at 240 to 250°F., which would make the hearts very soft and the brine very cloudy or jelled. Samples are taken regularly by the cannery inspection service of the State Board of Health for checking the pH value.

Some of the larger artichokes that are too mature for canning as artichoke hearts are trimmed by machine in such a manner that all the leaves, or scales, are discarded and only the bottom "buttons," or "cups," remain. These are hand-trimmed, blanched in citric acid solution, and canned in about the same manner as the hearts, but are processed 45 min. at about 212°F.

The packing of artichoke hearts in olive oil, according to Clifford Smith of the Owens-Illinois Glass Company, is conducted about as follows: Trim off stem and blossom ends of small artichokes and remove outer leaves to give tender hearts. Blanch 5 min. in 30-grain vinegar (3 per cent acidity) at the boiling point in order to reduce the pH value to a safe level and to collapse the tissues so that a full jar is obtained after packing. Drain several hours on wooden slat trays in order that the oil used in packing will "wet" and penetrate the hearts. In some cases the hearts are stuffed with pimiento, garlic, or red-pepper flesh. Pack in glass jars. Add olive oil at 130°F. to fill. Let stand to permit absorption of some of the oil. Again add oil to fill. Seal jars under vacuum. Process in water at 212°F. for 25 min. in a closed retort under sufficient pressure to keep the lids on the jars. Cool in water to about 100°F.

Artichoke hearts are also packed in glass in wine vinegar. They are first blanched in wine vinegar of 3 to 3.5 per cent acidity and packed at once in glass jars in the strained vinegar in which they were blanched. The jars are sealed in vacuum and processed, as described above for artichokes, in olive

oil. They may also be packed by blanching in boiling 1 per cent citric acid solution, draining, packing hot in glass jars, adding 0.25 per cent citric acid solution, heating to 140 to 145°F., sealing under vacuum, and processing 25 min. at 212°F. in a retort in water under air pressure. The ratio of glass-packed hearts to liquid is set by the California State Board of Health at not more than 60 per cent by weight of artichokes to 40 per cent of liquid.

ASPARAGUS
(Asparagus officinalis)

Most of the asparagus in California for canning purposes is grown in the delta lands of the Sacramento and San Joaquin Valleys, and the largest canneries in this district operate their own asparagus fields. It is grown also in other states, notably New Jersey, Washington, Illinois, South Carolina and Michigan, in decreasing order in respect to acreage. According to the U.S.D.A. there was 126,258 acres of commercially grown asparagus in the United States in 1945, of which about one-half was located in California. In 1934, according to Hanna (1947), California packed over 90 per cent of the canned asparagus produced in this country; in 1945 it canned only 63 per cent of the total.

The Mary Washington is the principal variety grown in California, whereas in other states the Martha Washington is grown extensively. In 1956 the total United States packs were green 4,252,000 cases, white 1,993,000 cases; the California packs were green 1,795,000 cases, white 1,993,000 cases, according to the *Western Canner and Packer.*

Cultivation. The delta lands are especially desirable for the culture of asparagus for the following reasons: The soil is a peaty loam, which permits the stalks of the asparagus to develop without distortion and permits them to reach large size in a short growing period. During the growing season the stalks grow from 4 to 6 in. per day. The soil is very rich and usually requires no fertilizing. Most of these lands are lower than the surrounding slough and rivers, are protected by levees, and are watered by irrigation obtained by siphoning. Because of the porous nature of the soil, it may be irrigated from narrow ditches by subirrigation or lateral percolation, without the necessity of flooding the soil. This permits cultivation to obtain a light dusty mulch that protects the ground from baking and "crusting." The plants are grown from seed in nurseries, and later planted in the field. A small cutting is obtained at 2 years. The beds last for 16 to 18 years.

Harvesting. During the first few weeks of the season the stalks are cut for Eastern shipment.

Cutting. Until rather recently only white asparagus was canned in California. A few years ago, owing to the increased popularity of the all-green asparagus in the fresh vegetable markets, several canners placed a moderate

quantity of the canned all-green asparagus on the market as an experiment. It was an immediate success, and at present all commercial canners pack it. It is rapidly overtaking the canned white asparagus in popularity. It is richer in flavor and vitamins than the white.

The green asparagus is allowed to grow through the surface to the necessary height. Preferably, however, the buds should not open to any great extent.

During the first 2 or 3 weeks of the cutting season, in late March and

FIG. 44. Harvesting asparagus for canning or freezing. In foreground power-driven pickup cart for transportation of asparagus to field house. (*After Hanna, Univ. Calif. Ext. Circ.* 91, *revised* 1947.)

early April, most of the asparagus is shipped fresh to the local and Eastern markets. When the supply exceeds the demand for the fresh asparagus, canning is begun.

White, asparagus is grown in ridged rows and is cut beneath the soil. Workmen—usually Filipinos, Mexicans, Japanese, or natives of India—walk slowly along the rows, and where they see slight bulges of the surface soil or the protruding tip of a stalk, they insert a broad, sharp chisel through the soil, cutting the stalk to a length of 8 to 10 in. They place the stalks in neat, small piles on the ridge of soil. Within a few minutes they are gathered up by another workman, who places them in a horse-drawn or tractor-drawn boxlike sled and takes them to the washing and cutting shed (Figure 44).

Washing and Trimming. In order to prevent staining of the stalks by the drying on of adhering soil, the stalks are rinsed thoroughly in water. In most sheds the stalks are carried by chain conveyer to a circular knife, which cuts them to length automatically. They are also washed by sprays. The loss in trimming is said to be about 18 per cent.

Receiving. The washed and trimmed asparagus is placed dripping wet in lug boxes; these are usually lidded to hold the stalks in place and are then promptly transported by truck or boat to the cannery. It is essential that the asparagus be canned as soon as possible so that it will not become tough and bitter. At the cannery the asparagus is either taken at once to the sorting tables or is stored for a few hours in a cooled, well-ventilated room.

Inspection. The deliveries from the different growers are carefully inspected, the amount of blemished asparagus, butts, etc., is carefully determined, and the weight of the asparagus unsuitable for canning is deducted from the amount delivered by the grower. It was formerly a common belief that California white canned asparagus was artificially bleached by sulfur fumes or other chemical means, but this is not the case. The white color is obtained by cutting the asparagus before it protrudes from the ground.

TABLE 18. SIZE GRADES FOR CALIFORNIA CANNED ASPARAGUS

Size	Approximate diameter of base of spears, in.	Range of number of spears, tips, or points per container		
		No. 1 (Eastern)	No. 300	No. 2
No. 1, Small	⅜	31–40	39–51	51–67
No. 2, Medium	½	23–30	26–38	34–50
No. 3, Large	⅝	17–22	19–25	25–33
No. 4, Extra Large	⅞ or over	7–16	9–18	12–24

SOURCE: After U.S. Department of Agriculture, Agricultural Marketing Administration, 1945.

Precooling. In most plants the asparagus is cooled shortly after delivery from the fields in order to arrest growth of the spears which results in lengthening and decrease of diameter of the blossom ends. Precooling also greatly retards deterioration in flavor and toughening of the texture. Various methods of precooling are followed. In one procedure the lug boxes of asparagus are placed by lift truck into a large tank of refrigerated water and cooled to 40°F. or lower. Another means of cooling is by hydrocooler, in which the boxes of asparagus pass slowly in an enclosed space through sprays of water, cooled by circulation over cakes of ice. In one cannery a

thick layer of crushed ice was placed over the asparagus in the open lug boxes during the 1954 season.

Cutting. Formerly the spears were size-graded and sorted for color and quality by hand into small 3-lb. boxes, and as many as 11 sizes and color segregations were made. They were then passed on a belt beneath a circular, rapidly revolving knife that cut the stalks to desired length for canning. Because of the present high cost of labor, fewer size grades are now made and operations are mechanized in so far as possible.

One procedure is as follows: The spears are placed with blossom ends flush against the guard wall of the conveyer. Lugs on the chain-type conveyer carry the spears to a circular knife or band saw that cuts off the butts which are discarded. A second knife or band saw cuts off about 1½ in. of the butt ends of the spears, which are known as "center cuts." A third cut may be required for spears for the smaller size of cans or for "tips." Some of the center cuts are canned for soup stock or for other purposes; some are discarded. They are sorted on a rubber belt to remove the unfit cuts.

The trimmed spears are vigorously washed in sprays between revolving brushes that loosen and remove "patches" of adhering soil. They are given a preliminary sorting to remove crooked, insect-damaged, badly stained, and otherwise inferior or unfit spears. They may then be given another brush-and-spray wash.

Blanching. The stalks are next blanched on a woven-wire conveyer in live steam for 1½ to 3 min., usually about 2 min. The blanched asparagus is sprayed and brush-washed and delivered to the canning belt.

Grading and Canning. From the canning belt the spears are sorted for size and color and placed blossom end up in cans. In a typical plant in 1955 the spears were graded "by eye" into three size classifications, each classification containing spears of two or three different diameters. In one plant the largest classification consisted of mammoth and larger sizes and large, the second classification contained medium and large, and the third classification the smaller sizes (Table 18).

Asparagus that is cut for canning as white spears usually contains a good many specimens that have green or purple "tips" (colored blossom ends). These are usually sorted out and canned as green tips. The white spears are canned as "all white."

The green spears are usually fairly even in color but are sorted for quality and size.

In several plants mechanical size graders have been used and supplemented by hand sorting. At present such graders appear to be more or less in the discard.

Crooked spears and those that have "blossomed" may be cut into short pieces and canned as cut asparagus. In a cannery visited in New Jersey in 1951 much of the green asparagus, including perfect spears, was cut into

short lengths before canning. Evidently a considerable demand exists for this product. The waste butts were discarded at one time by dumping them in the Sacramento or San Joaquin Rivers; but the State Fish and Game Commission now objects to this practice as the decaying organic matter is believed to be harmful to bass and other game fish. Some butts have been dried in the sun for sale as stock feed, but as asparagus contains 95 per cent or more of water, yields are very low. Much of the waste is spread in the fields where it dries and is plowed under later as a soil improver. If steamed and pressed, a juice is readily obtained which has been found suitable by the Western Regional Laboratory of the U.S.D.A. as a culture medium for growing certain microorganisms for production of antibiotics. It can also be filtered, diluted, and used as a liquid in which to can asparagus, giving a product of rich flavor.

Cans. Until a few years ago most of the cans used for asparagus were rectangular in cross section for the reason that it was thought that such cans hold the stalks more tightly than do cylindrical cans and would, therefore, prevent movement in the can with consequent breakage of the blossom ends. However, it has been demonstrated that the stalks retain their form well in cylindrical cans, and they have virtually replaced the square cans for asparagus. The sizes of cans in common use in California are the 211×409, the No. 1 Tall, Tall Picnic, No. 2, 300×409, and the No. 10.

Brining and Exhausting. Formerly a dilute brine of about 2 to $2\frac{1}{4}$ per cent salt content was added and the cans of white asparagus were exhausted in live steam in the usual manner. A common procedure, especially with green asparagus, is to add salt from an automatic dispenser and fill with hot water, or fill with hot water and then add salt by dispenser; in either case the cans are sealed at once in an atmosphere of steam. Some canners, however, exhaust the filled cans and seal the cans in plain double seamers.

Processing. The sealed cans are processed in retorts at 240 or 248°F. under the supervision of an inspector of the cannery inspection division of the state board of health. At present the official processing times for white asparagus at 240°F. are No. 1, No. 2, and smaller cans, 24 min.; No. 10 cans, 35 min. At 248°F. the times are No. 1, No. 2, and smaller cans, 12 min.; No 10, 15 min. For all-green asparagus the times at 240°F. are No. 1, No. 2, and smaller cans, 26 min.; No. 10 cans, 35 min. At 248°F. the times are No. 1, No. 2, and smaller, 13 min.; No. 10 cans 15 min. The cans must be processed in an upright position in order to permit convection currents in the cans during retorting.

Darkening of Green Canned Asparagus. Occasionally when a can of green asparagus is opened and the contents allowed to stand, the brine darkens and may become almost black. The stalks also are affected. Research by the National Canners Association research staff in California

and the Food Technology Department of the University of California has definitely established that the reaction causing the darkening is between iron from the tin plate and a compound in asparagus known as rutin. The darkening, according to the National Canners Association, is usually associated with a higher than usual pH and occurs more frequently in large than in small cans. Encouraging results toward control of the difficulty have been attained in National Canners Association experiments by the addition of calcium citrate to the brine used in canning and by the use of alum in the blanching water (see also Chapter 11).

Wiegand of the Oregon Experiment Station reported a number of years ago that the addition of a small amount of citric acid to the canning brine greatly minimized the darkening.

Yellow Crystals. Frequently yellow crystals of a flavonol glucoside, rather waxy in texture, form in canned asparagus, according to H. Campbell. They are related to the tannins.

Thermophilic Spoilage. At one time, considerable loss was incurred because of spoilage (often gaseous) of canned asparagus by thermophilic heat-resistant bacteria. By thorough washing to reduce soil contamination to the minimum and by use of more severe processing, most of this form of spoilage has been eliminated.

United States Grades. Federal standards for Fancy, Choice, and Standard grades have been established and are obtainable from the U.S.D.A.

GREEN BEANS
(Phaseolus vulgaris)

While not so important as canned peas, the annual pack of canned green beans amounts to about 20 million to 25 million cases annually. The beans should be of deep green color, crisp and tender, fleshy, and as free from fiber and strings as possible. In the Western states the Blue Lake variety is preferred for canning and freezing. The Refugee, 1,000 to 1, and various selections of the Stringless Green Pod varieties are grown successfully for this purpose in the Eastern and Middle Western states. Owing to the inroads of the mosaic virus disease of green pod beans, in the East and Middle West, it has become necessary to develop mosaic-resistant varieties by selection and cross-breeding. Walker of Wisconsin Agricultural Experiment Station recommends the following: Michigan Robust, U. I. Great Northern, U.S. No. 5 Refugee, Wisconsin Refugee, and Idaho Refugee.

Picking. In Oregon and California the Blue Lake and Kentucky Wonder beans are grown on strings attached to heavy galvanized wire strung about 5 to 6 ft. above ground level between heavy posts. The vines are irrigated frequently, usually by overhead sprinkling.

In one large plantation in Oregon the entire field was picked once a week

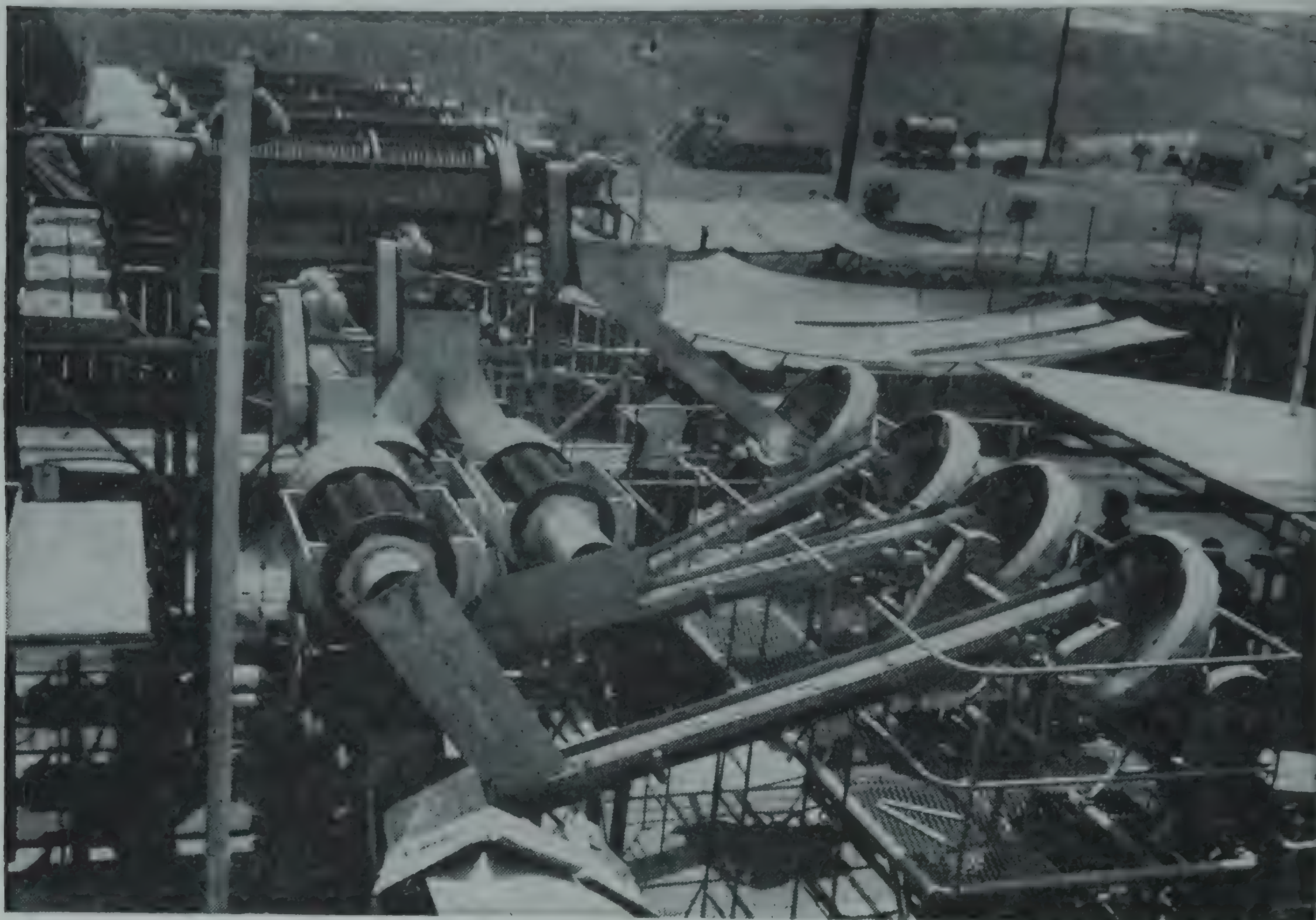


FIG. 45. Outdoor green bean processing line. Showing size graders, snippers, and cutters at Case-Swayne Co., Inc., Santa Ana, California. (*Western Canner and Packer.*)

and irrigated between pickings. The beans are picked into buckets, principally by women and by children of high-school age. The buckets are emptied into sacks. The filled sacks are weighed by the grower or field foreman and emptied into tote boxes, each holding about 1,000 to 1,200 lb. In 1955 the pickers were paid a base rate of 2½ cents per pound plus a small bonus.

The tote boxes are loaded on to trucks by lift truck and transported to the cannery promptly; some beans are delivered in sacks rather than in tote boxes.

Size Grading and Shipping. At the cannery the beans are dumped into a hopper or conveyer and conveyed to the size graders. These consist of revolving cylinders with slots of various diameters through which the beans fall on to conveyers that carry them to the snippers. In one large Oregon plant three size classifications were made in the first size grading. These were sizes 1 and 2 (the smallest beans), sizes 3, 4, and 5, and sizes 6 and 7, the largest beans. In this plant the 7s were later discarded because they were of too large diameter and too ripe (Figures 45 and 46).

The beans then were carried through snippers consisting of metal cylinders having narrow slots. As the cylinder revolves, the ends of the beans are caught in the slots, and fixed knives lying snugly against the lower

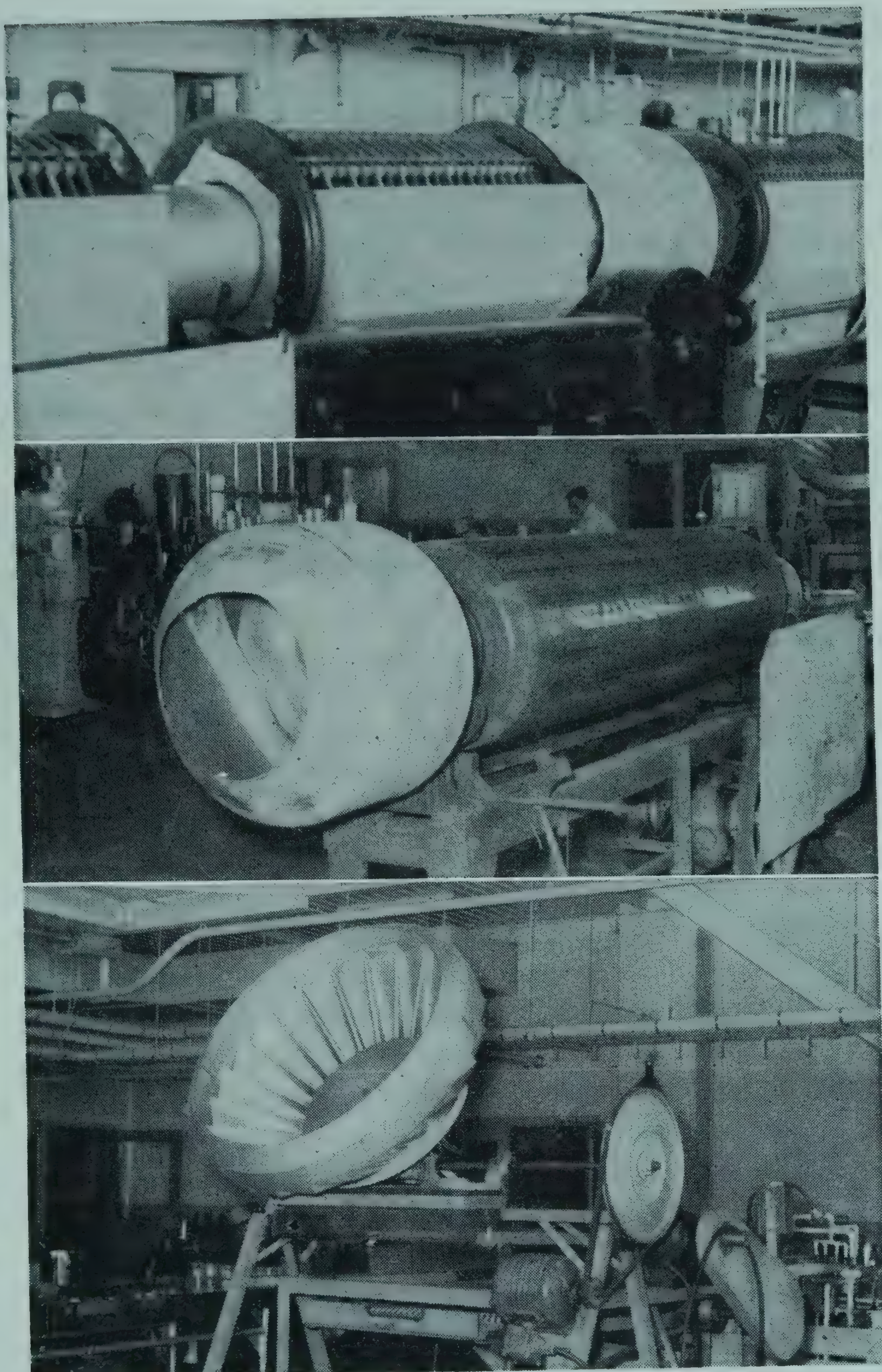


FIG. 46. *Upper:* Green bean size graders. *Center:* Green bean snipper. *Lower:* Green bean cutter. All in pilot plant of Oregon State College, Food Technology Department, Corvallis, Oregon.

surface of the cylinder cut off the tips and stems that have been caught in the slots.

The snipped beans are inspected, and any that have escaped snipping are snipped by hand or returned to the snipping line.

The beans are then regraded by machine for size into individual sizes.

Cutting. The sizes 1 and 2 are canned whole. The larger beans are cut crosswise by machine into lengths of 1 to 1½ in., 1 in. being more common for canning and 1½ in. for freezing. Some beans, usually of smaller size, are cut lengthwise as "French-cut" beans; but this is done after blanching, because if cut before blanching water-soluble nutrients are lost and the beans will have a washed-out flavor. Usually "cross-cut" beans are cut before blanching.

The cut beans are screened to remove fines, and then go to the nubbins-removing machine; this is a large revolving cylinder with numerous small cups which pick up and remove "nubbins," the short pieces. These may be canned in No. 10 cans for soup stock or other use.

Blanching. The cut beans as well as the whole No. 1 and 2 sizes are blanched, usually in hot water at 185 to 190°F. rather than in steam, for about 1½ to 2 min. to wilt the beans slightly and thus give better-filled cans. At higher temperatures, or after a longer period at 185 to 190°F., the skins are apt to "sluff," giving a ragged appearance. As previously mentioned, small beans for cutting as French style are blanched before cutting. In this case the blanched whole beans are returned to the French-style cutters and cut into shoestring-shaped pieces.

Canning. Cut beans are filled by machine by volume. The machine is similar to that used for peas (see illustrations in the section on canning of peas). A plunger beyond the filler automatically levels the fill of each can.

The cans are then filled with hot water, and dry salt is added by dispenser; or a brine of 8° salometer is added to fill the can, and the can is heated in a steam exhaust box for about 5 min.

The cans are sealed hot or are steam-flow-sealed.

In the Northwest the 303 size can is the most popular. Number 1 Tall and No. 10 cans are also used.

Processing. In general the National Canners Association temperatures and times for still retorts are used in processing the canned products. In one large Oregon cannery, however, the 303 size cans were processed in 1955 at 248°F. for 11 min. in a continuous FMC pressure retort, or 16 min. at 242°F. in a still retort. Number 10 cans were given 244°F. for 23 min. in a still retort. Another cannery used 252°F. for 20 min. for No. 10 cans in a still retort. A third canner used 240°F. for 25 min. for size 303 and 40 min. for No. 10 cans.

The National Canners Association, December, 1955, recommends the process times and temperatures in a still retort given on page 233.

As will be noted, the required process varies slightly with the initial temperature of the can's contents, i.e., according to whether it is sealed cold, as is sometimes the case in steam-flow or vacuum sealing, or sealed at a higher temperature.

Can name	Dimension	Initial temperature, °F.	Time at:		
			240°F., min.	245°F., min.	250°F., min.
No. 2 and smaller	307 × 409 and smaller	70	21	16	12
		120	20	15	11
No. 2½	401 × 411	70	26	19	15
		120	25	18	14
No. 3 Cylinder	404 × 700	70	32	22	18
		120	30	20	16
No. 10	603 × 700	70	37	27	22
		120	35	25	20

WAX BEANS

Wax beans are similar in general properties to green pod beans except in color. The methods of preparation and canning are similar to those used for green beans. Sorting must be more carefully done, however, as blemishes are more conspicuous on the wax beans.

BROCCOLI, BRUSSELS SPROUTS, CAULIFLOWER, LETTUCE, AND CABBAGE

These are common fresh winter vegetables available throughout most of the year in fresh form. However, some broccoli and "sprouts" are canned, but very little fresh cabbage. Cabbage is usually converted into sauerkraut before canning (see Chapter 22, Pickles).

Broccoli for canning is usually grown in a cool climate such as coastal sections in California or the cooler valleys of Oregon. It resembles sprouts in flavor but is like asparagus in appearance. Wiegand of Oregon Agricultural College recommends that it be trimmed, soaked in cold dilute brine for about 24 hr., blanched in dilute boiling brine about 3 min., chilled in water, canned in No. 2 cans, exhausted, and processed at 240°F. for 30 min. However, usual practice consists in washing, trimming, steam blanching, spray or flume cooling, canning, brining, exhausting, sealing, processing at 240°F. for 30 to 35 min., and cooling.

Sprouts are broken from the head, sorted, blanched about 4 min., chilled thoroughly in cold water to prevent matting in the can, canned in dilute brine, exhausted thoroughly, and processed at 240°F. for 20 min. in No. 2 cans or 25 min. in No. 2½ cans.

Cauliflower is handled in a manner similar to that for sprouts except that it is advised that the curds be blanched in boiling dilute citric acid to prevent graying of the color in the cans. The National Canners Associa-

tion recommends processing 20 min. at 240°F. for Nos. 1, 2, and 2½ cans if initial temperature is 140°F. or higher; 21 min. if sealed cold.

Cabbage may be trimmed, cut into sections, steamed until tender (steaming is preferable to a water blanch as less of the soluble food values is lost), canned in dilute brine of 1½ per cent salt, exhausted, and processed in No. 2½ cans at 240°F. for 40 min. or at 250°F. for 25 min. and in No. 10 cans at 240°F. for 60 min. or at 250°F. for 35 min. In order to arrest cooking after removal from the retort, the cans must be cooled very promptly and thoroughly.

Head lettuce becomes brown and soft if retorted but gives a very satisfactory canned product if trimmed, sliced, blanched in steam 4 to 5 min., canned in 7 to 8° salometer brine acidified with 0.75 per cent citric acid, exhausted, and processed at 212°F. for 60 to 75 min., depending on size of can.

CARROTS
(Daucus carota)

The pack of canned carrots in the Western states in 1956 was 985,000 cases, and the total United States pack was 2,706,000 cases, according to the *Western Canner and Packer*. In addition, a considerable quantity is canned in the form of baby food; and a moderate quantity of diced carrots mixed with peas is canned.

Carrots are canned in diced, julienne, or shoestring style, sliced, halved, quartered, and whole. Varieties for canning should have a smooth contour free of deep folds or wrinkles, tender texture, and flesh of attractive orange color. The carrots should not have a white or light-yellow core, but the flesh should be well colored throughout.

The Red Cored Chantenay, Danvers Half Long, and Imperator are important varieties grown in California for the fresh market and for canning or freezing. They are usually grown under irrigation in this state. They are pulled for canning or freezing while still young and tender. The tops are removed in the field, and the carrots are usually delivered to the cannery in lug boxes or burlap bags. Tote boxes holding several hundred pounds of carrots are also used. They are handled on pallets by fork-lift trucks, and their use considerably reduces the labor cost of handling.

Carrots store well in cool or cold storage if the humidity of the air is maintained at a high enough level to minimize evaporation of moisture. If the carrots "dry out" excessively, they become limp and rubbery and suffer in flavor. Best quality is attained by canning soon after harvesting.

At the cannery they are thoroughly washed, usually in a rotating drum with heavy sprays of water to dislodge and remove adhering soil that would

otherwise collect as mud in the tank of the lye-peeling machine or interfere in abrasion peeling.

They are also size-graded in order to separate the young, smaller sizes from the larger, a common sizing being 1 in. or less in diameter, 1 to 1¼ in., and above 1¼ in. Some of the smaller sizes are canned whole; the larger ones are sliced or diced or cut in julienne strips. Some may be cut lengthwise into quarters or halves. If too mature the flesh is apt to be fibrous, light in color, and of poor flavor and there is apt to be a prominent central core of light color.

The washed carrots are peeled in one of three ways, viz., by abrasion peeler such as used for potatoes, by hot lye solution, or by high-temperature steam peeling, as described in the chapter on peeling, washing, and blanching. In lye peeling a solution containing 3 to 10 per cent of NaOH is used, preferably in a spray-type lye peeler such as is used in lye peeling of peaches. If the carrots are to be abrasion-peeled, a short blanch at 185 to 190°F. tends to loosen the skin and thus facilitate peeling. In steam peeling the carrots are conveyed continuously into a closed chamber, heated briefly at about 300°F., and then ejected continuously from the heating chamber. Since the skin and flesh immediately beneath the skin are at a very high temperature, steam forms with explosive effect beneath the skin when the carrots emerge from the heating chamber and forces it off the vegetable with a minimum loss of flesh. Following either lye peeling or steam peeling, the disintegrated skins are washed away under heavy sprays of water in a rotating drum washer.

The carrots are then trimmed by hand from a slowly moving belt to remove the roots and the green flesh at the top of most of the carrots. Defective areas are also trimmed off.

The larger carrots are sliced or diced or cut into "shoestrings" by a machine such as the Urschel or FMC vegetable-cutting machines. Diced or julienne-cut carrots should be screened under sprays of water to remove fines. The diced carrot pieces should be ¼ to ⅜ in. in diameter. The smallest carrots may be canned whole. In any case they are then usually blanched in live steam or in water at 190°F. for 2 to 4 min. The whole carrots are packed into cans asparagus-style by hand, and the various types of cut carrots are filled by machine or by hand-pack (semiautomatic) filler.

Salt can be added by dispenser to each can, the can then filled with very hot water and sealed hot, or hot dilute brine (6 to 8° salometer) may be added, or cold brine added and the cans exhausted at 200 to 205°F. and sealed hot. Also prevacuumizing and vacuum sealing or steam-flow sealing can be used.

The National Canners Association (1955) recommends the following processing times and temperatures:

Can name	Dimensions	Initial temperature	Time at:	
			240°F., min.	250°F.
2½ and smaller	401 × 411	70°F.	35	23
	and smaller	140°F.	30	20
No. 10, not sliced	603 × 700	70°F.	45	30
		140°F.	40	25
No. 10, sliced	603 × 700	70°F.	50	35
		140°F.	45	30

Carrots and Peas. A mixture of diced carrots and green peas is canned in considerable quantity. They must be well mixed before canning and without undue crushing or breaking of the peas; consequently the peas should not be too heavily blanched before mixing. The ratio of carrots to peas is usually from 50:50 to 60:40.

The brining and can sealing are conducted about as previously described for carrots. The National Canners Association (1955) recommends a process of 45 min. at 240°F. for No. 2 and smaller cans if initial temperature of 70°F., or 40 min. if initial temperature is 140°F. Corresponding processes at 245°F. are 30 and 25 min., and at 250°F., 20 and 18 min. For No. 10 cans the processes are 60 and 55 min. at 240°F., 45 and 40 min. at 245°F., and 28 and 25 min. at 250°F.

LIMA BEANS
(Phaseolus lunatus)

Green Lima beans are canned after being shelled from the pods. The bush variety is grown for canning purposes and is handled in much the same manner as peas.

Vining. The vines are harvested in somewhat the same manner as peas, when most of the beans have reached the stage of maturity most desirable for canning. The vines are passed through a pea viner, which threshes out the beans from the pods and separates the vines and pods from the beans, as described elsewhere for peas, except that the machine is operated at slower speed and the sieve openings are larger. They should be canned promptly after vining, as delay results in rapid deterioration in color, flavor, and quality.

Grading. The beans are cleaned in clipper mills and graded for size over screens having openings of $^{24}/_{32}$, $^{30}/_{32}$, $^{31}/_{32}$, and $^{32}/_{32}$ in. diameter. The various sizes are known as Tiny, Fancy, Medium, Standard, and Mammoth. The smallest sizes are the tenderest and sweetest and the most desirable for canning purposes.

The beans, like peas, are passed through a tank of brine of such density that the green beans float and the overmature beans sink. Conveyers separate the two grades.

Before canning, the overmature beans may be soaked in water until plump and canned as "soaked Lima beans."

Blanching. The green beans are blanched in water at 190 to 200°F. or in boiling water as described elsewhere for peas. They are filled hot into cans by automatic filling machine, and dilute brine added to fill. The ratio of brine to beans is such that a well-filled can results after processing. The cans require no exhaust if filled hot.

Processing. Usually the National Canners Association processes for various sizes of cans are followed. These are for cans of No. 2 size and smaller at 240°F., 35 min. if initial temperature is 140°F. or above; if initial temperature is 70°F., the process at 240°F. is 40 min. The corresponding times for No. 3 cans are 50 and 55 min. If processed at 250°F., the times for No. 2 and smaller cans are 18 and 20 min., and for No. 10 cans 30 and 35 min.

CORN
(Zea mays)

The canning of corn is one of the most important of the vegetable-canning industries, the average annual production being approximately 33 million cases. The most important corn-canning states are Illinois, Indiana, Iowa, Maine, Maryland, Minnesota, New York, Oregon, Washington, Michigan, and Wisconsin. Corn is packed in a number of other states of the Middle West and East, but very little is canned in the Southern states and none in California.

Production Statistics. The output of canned corn varies considerably from year to year, largely because heavy plantings follow years of high prices and light plantings follow years of low prices. Some of the variation noted in Table 19 is due also to variation in yields per acre.

In 1954 the packs, according to *Western Canner and Packer*, by states or regions were Wisconsin 8,232,000 cases, New York 1,308,000, Maryland-Delaware 2,036,000, other Middle Western and Eastern states 21,068,000, Oregon and Washington 3,635,000, and other Western states 581,000 cases.

Sweet corn is of two classes: one in which the kernels are arranged in regular rows, and the other in which the kernels are arranged irregularly on the cob. Stowell's Evergreen and the Country Gentleman are representative of the respective types. There are also two classes as to color, white and yellow.

The Country Gentleman variety possesses smaller kernels than the Evergreen and is generally of better canning quality. The four most im-

TABLE 19. PRODUCTION OF CANNED CORN, 1905 TO 1945

Year	Cases of 24 No. 2 cans	Year	Cases of 24 No. 2 cans
1905	13,018,665	1916	9,130,000
1906	9,136,960	1917	10,803,000
1907	6,654,044	1918	11,721,860
1908	6,784,000	1919	13,550,000
1909	5,787,000	1920	15,040,000
1910	10,063,000	1925	24,320,000
1911	14,337,000	1930	15,692,000
1912	13,109,000	1935	21,471,000
1913	7,283,000	1945	29,538,500
1914	9,789,000	1954	36,761,000
1915	10,124,000	1955	29,208,000

SOURCE: After The Canning Trade Almanac.

TABLE 20. COMPARATIVE CANNED-CORN PACKS OF LEADING CORN-CANNING STATES

State	Cases, 1920	State	Cases, 1945
Illinois	2,271,000	Illinois	4,417,384
Indiana	861,000	Indiana	2,083,702
Iowa	3,246,000	Iowa and Nebraska	3,356,801
Maine	1,588,000	Maine, Vermont, and New Hampshire	905,643
Maryland	2,217,000		
Minnesota	643,000	Maryland and Delaware	2,639,312
New York	829,000	Minnesota	4,962,876
Ohio	1,544,000	New York	1,351,160
Delaware, Pennsylvania, Missouri, Michigan, Vermont	764,000	Ohio	1,124,937
		Wisconsin	5,962,722
		Other states	2,734,016
Wisconsin	590,000		
Other states	487,000		
Total	15,040,000	Total	29,538,553

SOURCE: After Canning Trade Almanac and *Western Canner and Packer*, 1946.

portant "regular" varieties formerly were Golden Bantam, Crosby, Country Gentleman, and Stowell's Evergreen. See hybrid varieties below.

Culpepper and Magoon studied the relative merits of a number of sweet-corn varieties for canning purposes. They list, among others, Crosby, Potter's Excelsior, Narrow Grained Evergreen, Country Gentleman, Stowell's Evergreen (white varieties), Golden Bantam, Morse's Golden

Cream, and Vaughn's Bantam Evergreen. The Golden Bantam was a popular variety for whole-grain corn in brine and for brineless whole-kernel corn until the hybrid varieties came into general use.

In recent years sweet corn for canning and freezing has been greatly improved by crossing inbred strains selected for desired qualities of yield, color, disease resistance, flavor, etc.; or by crossing inbred with open-pollinated varieties. About eight years is required to develop a new hybrid. Amazing results have been attained, and nearly all commercially grown sweet corn is now of hybrid varieties. They give greatly increased yields, ears and corn of exceptional uniformity, and excellent flavor, color, and canning quality. Examples of "single" crosses are Golden Cross Bantam, Ioana, and Golden Hybrid 2409; and of "top" crosses, Top Cross Maine Bantam and Top Cross Sunshine.

Styles of Canned Corn. Most canned corn is packed in Nos. 2 and 303 cans and usually in one of two styles known in the trade as "Maine style" and "Maryland style," respectively. Maine-style corn is obtained by cutting through the kernels, scraping the remaining portions of the kernels from the cobs, and mixing the scrapings with the cut kernels. Enough water flavored with salt and sugar is added to give the desired consistency. Starch, also, is usually added. The product is creamy in texture when the can is opened and is the more popular of the two styles. It is also called "cream-style" corn.

Maryland-style, or whole-kernel, corn consists of the whole kernels cut from the cob and canned in brine; the cobs are not scraped.

A third style is double-cut corn, from overmature corn or from large kernels obtained by cutting the corn from the cob and cutting the kernels a second time by special knives to produce a creamed-corn effect.

In 1947 a fourth style of canned corn known as "cremogenized" was introduced. First the corn is cut from the cob as for whole-kernel style. Then some of the kernels are cut to a creamy consistency and mixed with the whole kernels. It is then canned in a manner similar to that used for cream-style corn. Dr. C. O. Ball of Rutgers University has done much research on the product. The United Company, Westminster, Maryland, makes the equipment and supplies information on the process.

Brineless whole-kernel corn, vacuum-sealed in cans, has come on the market and has been very favorably received.

Culture and Harvesting. The corn is planted at time intervals so that there will be a succession in maturing, and thereby a long and continuous canning season. The field department must keep in close touch with the development of the corn in the various plantings and must decide when a given field of corn is at optimum maturity for canning. Corn that is too immature gives a sloppy or watery pack; if too mature the kernels become starchy and hard and the hulls tough and chaffy. The number of days

elapsing after the first appearance of the silk on the ear is said to be a useful guide; thus under Maryland conditions Magoon and Culpepper found, in testing 15 varieties of sweet corn, that the kernels were too immature on the fifteenth day and had passed their prime by the twenty-fifth day after appearance of the silks. In a cooler area the spread would probably be

FIG. 47. *Upper:* Harvesting ears of corn. *Lower:* Delivering corn at cannery. Salem, Oregon.

longer; in a warmer section, shorter. In their investigations the corn was of best maturity for canning at 15 to 19 days after appearance of the silk. The contents of the kernel should be creamy in consistency and not watery (too immature) or doughy (too mature).

Various tests have been used or devised to determine proper maturity for canning; a rough measure used by many field men is the thumbnail test, which consists in noting the pressure necessary to break the hull of the kernel with the thumbnail. Obviously, this test is not quantitative and is subject to a large personal equation. However, experienced persons can judge maturity quite well by its use if accompanied by judgment based on appearance and feel of the ears.

Burton suggested that a test based on the number of kernels that will float in a brine of specified density in a sample of 100 kernels cut from the cob be used to judge canning maturity, the density of the brine being chosen to fit the variety of corn and locality where grown.

He and others have found that the moisture content of the hulls of tough kernels is considerably below that of tender kernels, as shown in the following table.

TABLE 21. MOISTURE CONTENT OF HULLS OF COUNTRY GENTLEMAN CORN

Grade assigned by canner	*Moisture content of hulls, %*
Fancy	72
Extra Standard	71.8
Choice	70.0
Standard	67.0
Substandard	57.2

SOURCE: After Burton.

Culpepper and Magoon of the U.S.D.A. used a pressure tester to measure the toughness of the corn, and hence its fitness for canning. Kramer and Smith (1946) in Maryland have devised a method based on the volume of liquid expressible from a weighed sample of kernels in a specially designed press, which they have termed a "succulometer." Other tests that have been used or suggested are sugar content, starch content, the "tenderometer" test used for peas (see section on pea canning), and per cent of alcohol-insoluble matter, which is indicative of starch content.

In hot weather it is preferable to pick the corn in the "cool of the day" because it is then more crisp and succulent than when picked warm and is also less liable to lose sweetness rapidly after picking by change of sugar to starch.

Until fairly recently the ears were snapped from the stalks by hand and thrown into a truck that kept pace along the row with the pickers. At present, at least in the Pacific Northwest, the ears are harvested mechanically by a machine that cuts the stalks near the ground level and elevates them to a mechanism that cuts the ears off the stalks, and additional machinery separates the ears from the leaves and stalks and elevates the ears into a deep-bodied truck that is driven beside the harvester. The FMC machines seen in operation in Oregon did an excellent job with very few ears left in the field and very little damage to the kernels. The stalks and leaves were dropped to the ground behind the machine, and cattle were later pastured in the field. This material could be gathered by machine, put through an ensilage cutter, and stored in silos or fed to livestock, as is done with the waste husks and cobs from the cannery. The harvester takes two rows of corn at a time and can harvest 10 to 12 acres per day under the conditions observed in Oregon in 1955.

In this case the variety of corn was Northrup King's 18 Row Hybrid. The yield was 5 to 6 tons of ears per acre, and the price to the grower was $22.50 per ton.

Receiving and Storage. On arrival at the plant the load of corn is first weighed and is then driven to the dumping area. The truck is unloaded by hand or is driven onto a platform that tilts the front end upward, causing the corn to fall through a chute into a bin beneath the platform. Conveyers carry the corn from this bin to the huskers or to storage cribs, which should be well ventilated to prevent overheating and deterioration (Figure 47).

In several plants in Oregon the ears are dumped from trucks on to a large concrete slab outside the cannery. They are "bucked" by small tractor and push bar into a conveyer situated in a long slot in the pavement.

If most satisfactory results are to be obtained, the corn should be husked in the order in which it is delivered and upon the day on which it arrives at the plant. If stored in large piles, it is apt to sweat and become sour through the development of bacteria. If it is to be stored overnight or longer, it should be arranged in small piles to permit of good ventilation.

If allowed to stand too long before husking, much of the sugar of the kernels is transformed into starch and toughening of the hulls is apt to occur.

Husking. At one time corn was husked by hand for canning, but at present all the large canneries use mechanical huskers.

Conveying. The mechanical conveying systems are very complex but so arranged that the corn is handled mechanically practically throughout the entire canning process.

Huskers. There are several designs of husking machines, but all have one feature in common. This is a pair of rapidly revolving rubber or milled-steel rolls which catch the husks and remove them in much the same manner that wet clothes are carried through the rolls of a clothes wringer.

In one well-known husker the rolls are of semihard, very tough, black rubber with spiral groves running lengthwise of the rolls. Each roll is made up of three sections that are interchangeable. Most of the wear on the rolls is at the point where the ears first touch the rolls, and when worn this section is easily replaced. Most of the modern huskers are equipped with two sets of rolls and are known as "double huskers."

The rolls are spaced so that an ear cannot pass between them, yet are close enough together so that friction of the rolls against the ear loosens the husk, which is caught between the rolls and torn off. The rolls are slightly wider apart at the upper end where the larger proportion of the husks are removed. The rolls are so mounted that they can spread apart sufficiently to allow the husks to pass between them; but are then returned instantly to their former position by powerful springs.

In the modern huskers a hooklike device, or "husk ripper," loosens and

opens the husk on the ear before it reaches the rolls. The rolls then easily catch the husks and are apt to do a cleaner and more nearly perfect job of husking and removing of silks.

In the huskers seen in Oregon canneries fixed knives cut off both the butt and the silk ends before the ear reaches the husk ripper and husking rolls. In some huskers only the butts are removed.

Two operators, one at each side of the machine, place the ears on a lugged conveyer that carries the ears against the butting knives and

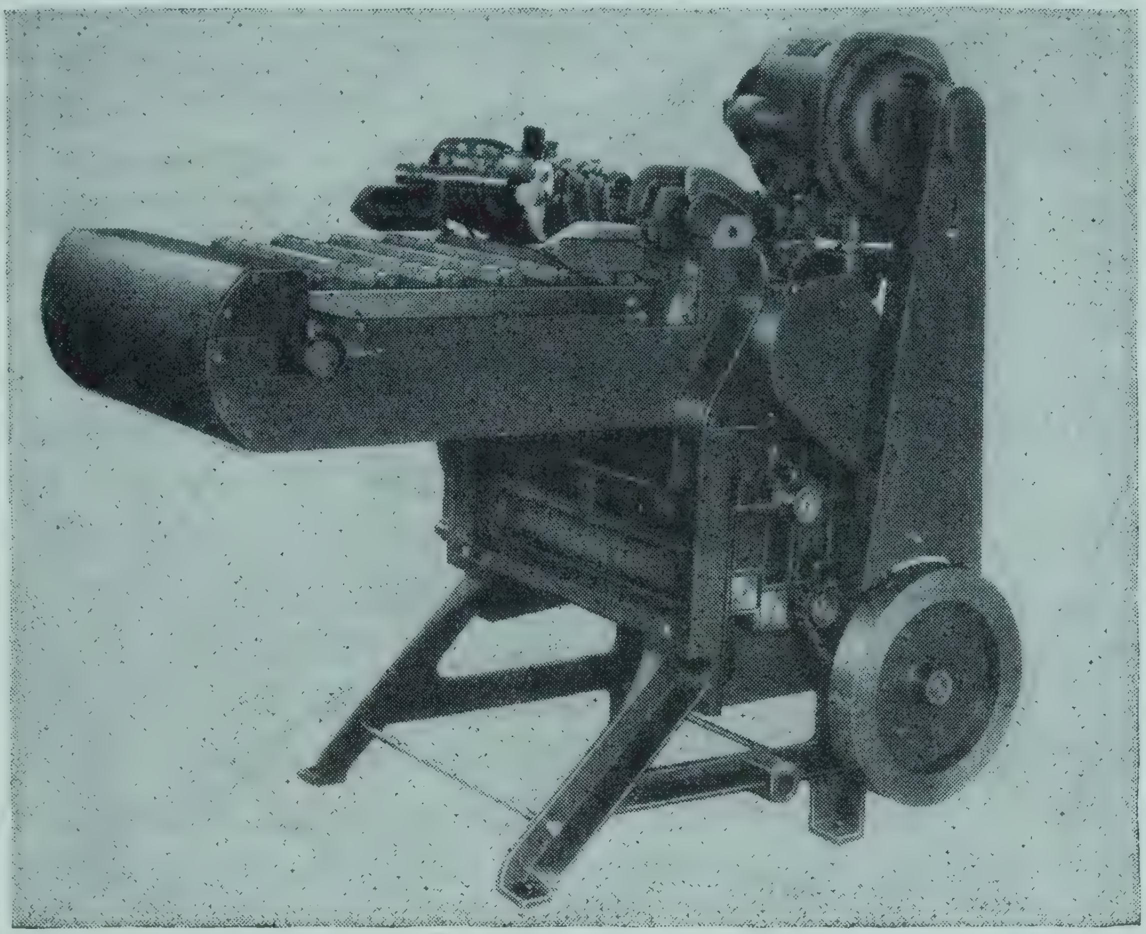


FIG. 48. Corn-husking machine. (*Sprague-Sells Machinery Corp.*)

through the husk rippers to the husking rolls. The rolls are kept wet with a spray of water during operation to prevent fouling. The rolls usually do a clean job of husking and remove most of the silk.

Modern huskers are usually equipped with individual motors and V-belt drive. The husked ears pass by way of an apron spout to the clean-corn conveyer for sorting and trimming.

Bins. A convenient and efficient means of delivering corn to the huskers is a long, narrow inclined chute or apron connecting a bin above the husker to the feed table at the husking machine. The operator then has at all times a supply of corn in a convenient position.

The husking machines are usually arranged in long rows, and all huskers in the line deliver the husked corn to a single clean-corn conveyer (Figure 50).

Precautions. O. S. Sells has indicated several important precautions to be observed in the operation and care of husking machines. He recommends

that the butting knives should be sharpened frequently, e.g., twice daily, in order that the machine may work smoothly and without excessive use of power. The husker rolls should be properly adjusted at all times. He recommends that medium-soft rubber rolls should be compressed $\frac{1}{8}$ to $\frac{1}{4}$ in. at points of contact and more tightly compressed at the discharge end than at the feed end, since most of the husks pass through the rolls at the feed end. In order to remove the thin surface layer of oxidized hardened rubber, the rolls of medium-soft rubber should be dressed or roughened before the start of each season. Rolls of semihard rubber may not need this treatment. To obtain clean husking, the machines must be supplied with ample power so that the rolls do not stop for an instant when they first grasp the husks. A long belt is less apt to slip at this point of the husking operation than is a short belt. Because of the heavy duty imposed upon them, all working parts must be well oiled. At the end of the season the rolls should be wrapped in paper and the machines coated with oil to check rusting and weathering.

The capacity of most single husking machines is rated at 60 to 80 ears per minute and of double machines at 120 to 160 ears per minute, approximately 2 tons per hr.

The husks and trimmings, which comprise about one-third the weight of the unhusked corn, are good stock food and are either fed direct or made into silage and used during the winter months. Conveyers carry the waste to the husk pile or to the silo. In Oregon canneries the husks and cobs are shredded for feeding fresh to cattle or for ensiling.

Silking the Corn on the Cob. The husking machines and trimmers remove most of the silk. In some factories the husked ears pass through a silking machine equipped with revolving brushes and rolls. The ears are carried forward through the brushes, which remove nearly all the silk and deliver the silked ears to the washing machine. Silking of the cob can be omitted if the work of the mechanical huskers and the trimmers is well done, and removal of remaining silk can be deferred until after the corn has been cut from the cob.

Inspecting and Sorting. If the ears are inspected after rather than before washing, much hand labor is eliminated. Customarily two sortings are made in some plants. In the first the improperly husked ears are returned to the husking department and the culls and trash discarded. In the second sorting the ears may be sorted into A and B grades, the A being used for Fancy and Choice canned corn and the B for Standard quality. Some ears are also sorted out for cream-style corn, usually the more mature ears.

Washing. Washing of the corn before cutting is desirable, to remove dirt, dust, earworm excreta, smut, and small pieces of husk and silk.

There are two satisfactory methods of washing: one by means of the silker-brusher washer described above, and the other by means of a revolving cylinder or conical reel, similar in design and operation to the rotary

tomato washer. It consists of an inclined revolving perforated or screen cylinder through which the corn passes under heavy sprays of water. According to Sells, the washer should rotate at from 12 to 15 r.p.m.

In tests made at the Agricultural Experiment Station at Ames, Iowa, it was found that a spray nozzle with a $\frac{3}{16}$-in. opening gave much better results than smaller nozzles, although more water was required. The increased efficiency more than counterbalanced the increased water consumption. At 15 lb. nozzle pressure the spray was found to spread 13 in. at 18 in. below the nozzle; at 20 lb. pressure the spread was 15 in., and at 25 lb., 18 in. Seven nozzles, the usual number per washer, will use 189 cu. ft. of water per hour at 15 lb. pressure, 210 cu. ft. at 20 lb. pressure, and 231 cu. ft. at 25 lb. pressure. At least 50 lb. pressure per square inch at the nozzle is recommended by Bitting.

The silker-brusher accomplishes practically the same results as the rotary washer, but it may be followed to advantage by a drum washer.

If the corn is washed immediately after husking and before sorting, a great deal of the labor used in sorting can be eliminated and trimming will be facilitated, because washing removes most of the silk, pieces of husk, smut, and worm evidence. In the rotary washer the ears are rubbed against each other vigorously, so that adhering dirt of all kinds is loosened and removed by the water sprays.

Some canners blanch the corn on the cob in water, at or near the boiling point, to coagulate the juice, for corn to be packed as whole-kernel (Maryland) style. This is done in at least one Oregon cannery in order to minimize loss of creamy juice in subsequent operations.

Cutting. During the early years of the corn-canning industry the corn was cut from the cob by hand, an expert cutter being able to cut corn for 1,000 cans per day in this manner.

In 1822 the first mechanically operated cutter was invented by Sprague. His machine has been improved upon but remains the basis upon which the improved machines are built. The knives were held under tension by rubber rings that adjusted themselves to the size of the ears, but rings required frequent replacement and later were replaced by metal springs. The circular head of this machine was later replaced by feed rolls having thin steel blades to force the ears into the cutter. This improvement resulted in more uniform cutting.

In the modern machine the ears are forced through curved knives that accommodate themselves by springs to the size of the ear. Scrapers beyond the cutting knives scrape the cobs for Maine-style corn. See Figure 49.

Two sets of knives in tandem may be used to double-cut the corn, the first pair of knives to cut about half of each kernel from the cob and the second pair to cut the remaining portion. This is done with overmature corn to improve its appearance and texture. For cream-style, i.e., Maine-

style, corn, part of each kernel is cut from the cob and the remainder is scraped off the cob mechanically by blunt blades. The scrapings are mixed with the kernels.

The corn should be fed to the cutting machines small end first, since the

Fig. 49. Corn cutter in operation. Note ear from which corn has been cut, emerging from cutters. (*Hunt Foods, Salem, Ore.*)

knives adjust themselves to the ear more satisfactorily than if the butt end enters the knives first.

The cutter knives must be sharpened frequently, under normal operating conditions once every 5 or 6 hr. Special grinders are used for this purpose.

The machines should be so arranged that working parts are readily accessible for repairs. Frequent oiling is necessary for smooth operation and clean cutting.

The cobs from the cutting machines are carried by a conveyer to the husk pile or to a cob shredder or crusher, where they are crushed or cut finely enough to be mixed with the husks for use fresh, for stock feed, or for siloing.

The cutting room should be well lighted to permit inspection of corn and machines. It should have a sloping concrete floor to permit frequent hosing down and should also have concrete walls to a height of 4 or 5 ft. for the same reason.

Inspection of Whole-kernel Cut Corn. In Northwest plants the cut corn to be canned as whole kernel is carefully inspected on a slowly moving belt and unfit material removed and discarded.

Flotation Cleaning and Silking Whole-grain Corn. In the Northwest plants visited by the author, the corn is next passed through a flotation separator, a shallow tank filled with water in which a paddle stirrer moves slowly. The corn sinks, and the trash floats and is removed automatically. The kernels then are conveyed by pump or conveyer to the silking and washing reels (cob reels). Each machine consists of four woven-wire reels (drums) carried in a single frame. The reels revolve, and the kernels fall through the screens. Cob particles, silk, and other foreign material are removed and separated from the corn.

The corn next comes in contact with traveling wires which remove remaining silk and shreds of husk. The corn then falls on to vibrating shaker screens which remove any residual trash, silk, etc., while the corn falls through the screen to the product-collecting pan, or sump. From this point it is pumped in water to a dewatering screen, and the dewatered corn is delivered to the can-filling machine, very similar to, or identical with, a pea filler.

Preheating. In at least one Northwest cannery the whole-kernel corn is heated by steam in a tubular heater on its way to the can filler and is filled hot.

Filling and Brining Whole-kernel Corn. A recently designed filling and brining unit, the FMC 15-station filler and briner, is described about as follows by the manufacturer.

It is a gravity-type filling and brining machine. The filling unit is equipped with 15 telescopic product-measuring pockets mounted on a revolving turret. The pockets measure the exact required amount of product, such as corn or peas, and discharge it into filling funnels from which the corn or other product falls by gravity into the cans. Cutoff plates automatically open and close the measuring pockets. If no can is positioned under the funnel, the discharge plate does not open and thus no spillage results.

The pockets rotate in succession under a supply hopper to receive their load. The hopper rotates and is equipped with an offset stud that agitates the corn or other product and thus prevents bridging, ensuring uniform fill of pockets and cans.

Below the hopper is a special drain that drains away any water entering the hopper with the corn, thereby preventing entry of such drainage water

into the cans. The cans travel on supporting tracks that can be vibrated if desired, in order to settle the product in the cans.

The filled cans travel from the filler to the briner, which is part of the unit. Hollow cylindrical measuring tubes within the brine tank separate a column of brine and fill it into the cans. The volume so delivered is adjustable to fit the needs of the product being canned. If a can is not in filling position, the filling valve remains closed. Up to 350 cans per minute can be filled and brined. The machine is designed for direct coupling to the can-closing machine.

The Brine for Whole-kernel Corn. According to Bitting, the brine for whole-grain corn usually contains from 1.5 to 2 per cent of salt and a somewhat greater per cent of sugar. One Northwest cannery stated that its brine for whole-grain corn consisted of 50 lb. of sugar, 15 lb. of fine-grain salt, and 100 gal. of water; corresponding to about 5 per cent of sugar and 1.5 per cent of salt. In this plant the cans are filled with brine at 115 to 120°F.

Closing and Processing Cans of Whole-grain Corn. The can should not be filled too tightly with corn or heat conductance will be retarded and the pack will be too solid. Bitting recommends 13.5 to 14 oz. by weight of whole-kernel corn per No. 2 can.

The filled cans pass beneath a "topper," a leveling plunger that automatically gives the proper head space in the can. In many plants the cans are then sealed in a steam-flow (or steam-vac) sealer. In some they are well exhausted in a steam exhaust box and sealed hot.

Until recently the No. 2 can was the most common container for corn for use in the home, but at present the 303 can is coming into widespread use, at least in the Pacific Northwest. It is somewhat smaller than the No. 2 can.

The National Canners Association (1955) recommends the following process times and temperatures for whole-grain corn in still retorts:

Can name	Dimensions	Initial temperature, °F.	Time at 240°F., min.	Time at 245°F., min.	Time at 250°F., min.
No. 2 and smaller	307 × 409 and smaller	100	55	40	30
		140	50	35	25
No. 3 Cylinder	404 × 700	140	65	45	35
No. 10	603 × 700	140	85	60	45
		160	80	55	40

In one large plant near Salem, Oregon, 303 and No. 10 cans of whole-grain corn were processed in 1955 in continuous agitating FMC retorts, the

303 cans at 250°F. for 14 min., and the No. 10 cans 28 min. at the same temperature. The cans were cooled in the same equipment.

In another plant the 303 cans were processed in a still retort at 240°F. for 50 min. Others were using the National Canners Association processes in still retorts.

C-enamel Lining. All cans used for the canning of corn, as previously stated in the chapter on can making, are lined on the inside with so called C-enamel (corn enamel), which contains zinc oxide. Unless it is used the small amount of H_2S formed during retorting will react with iron from the tin plate and form black particles of FeS. Zinc sulfide is white.

Vacuum-packed Whole-grain Corn. A popular style of canned corn is the whole kernel, vacuum-packed. On opening a can of this product it is found to be almost free of liquid. The No. 2 can contains about 12 oz. of corn after retorting and storage.

Only tender ears of fine quality should be used for this pack. The preparatory operations are conducted as previously described for whole-grain corn in brine. Thorough washing after cutting is essential in order to remove fines that would otherwise settle to the bottom of the can and detract from the appearance of the canned product.

The cans are filled completely or to a slightly heaped fill. A plunger automatically levels the fill before the can lid is placed on the can. Next a small amount of water, normally about 1 fl. oz. per No. 2 can, is added. The first operation only of seaming is given at first, i.e., the lid is not hermetically (airtight) sealed at this point, so that the air can be withdrawn in the vacuum sealer. The can next goes to the vacuum chamber of the automatic vacuum-can-closing machine, which is operated at as high a vacuum as feasible, preferably about 28 in. at or near sea level or within about 2 in. of a perfect vacuum at high elevations, such as near Salt Lake in Utah.

The cans are first thoroughly vacuumized, and then the final seaming (closing) operation is given. The National Canners Association recommended process for No. 2 cans of vacuum-packed corn is 55 min. at 240°F., 45 min. at 245°F., and 35 min. at 250°F. in a still retort.

During retorting the liquid in the can vaporizes to form steam, which greatly speeds up heat penetration by steam convection currents inside the can.

Young corn will take up very little water after canning, usually less than 1 oz., whereas more mature corn may require as much as 2½ to 3 oz. per No. 2 can. On the other hand, only tender young corn should be used for this product. As salt may cause toughening of the hulls, water is preferred to brine for this pack.

Lethal Rate. Bigelow and his associates have studied the resistance to heat of organisms causing the spoilage of corn and have based their recommendations for processing upon these data. Organism No. 26 required

214°F. for 1,180 min. for complete destruction of all spores in corn of a pH value of 6.1. Theoretically 1/1,180 of the spores were killed in 1 min. Bigelow designated this as the lethal rate, which he expressed as a decimal, in this case 0.0008. As the temperature increases, the lethal rate increases. Thus, at 245°F. it was 0.02740 for organism 26. Much work on heat-resistant organisms has also been done more recently by Esty and others of the National Canners Association since Bigelow and coworkers' early research. Nevertheless, the data given in Table 22 are useful.

Similar data were obtained for other retort temperatures.

Equivalent processing times for various temperatures are given in Table 22.

TABLE 22. EQUIVALENT PROCESSING TIMES FOR VARIOUS TEMPERATURES

Process temperature, °F.	*Time for sterilizing corn, min.*
260	56
255	64
250	78
245	96
240	129

SOURCE: After Bigelow.

Cutting Cream-style Corn. Ears destined for cream style are husked, and the husked ears inspected, sorted, washed, and desilked in the same manner as those to be used for whole-grain corn, but from this point the succeeding operations for the two styles of canned corn are quite different.

The knives of the cutter are adjusted to cut the kernels about in half. The ear then passes through scrapers that scrape the remaining portion of the kernel from the cob. These are set so that none or very little of the chaff from the cob is obtained. The scrapings and the cut kernels are mixed, giving a creamy mixture.

Silking Cut Cream-style Corn. While most of the silk is removed by the husking rolls and by the husked-ear silking machine, there is always a certain amount of silk which lies between the kernels and cannot be removed until the corn is cut. The silking machine previously described for whole-grain corn can be used also. A flat, vibrating screen, instead of the revolving reel previously described, is used for cleaning and silking cream-style corn.

It is customary to remove remaining silk after the corn has been heated. A special desilking machine is placed between the filling bowl and preheater. Revolving wires pick up and remove the silk which has become limp after cooking and is easily removed by the desilker wires.

Blending, Precooking, and Consistency Control. In a large cannery in the Pacific Northwest the cream-style corn, after desilking, undergoes the following treatment.

In a blender, also termed a batch mixer, the corn, water, sugar, salt, and starch are mixed in a stainless-steel tank, equipped with rotating paddles to mix the batch. The water and creamed corn are measured by volume, and the other ingredients are weighed. The starch is previously mixed with

FIG. 50. *Upper:* Sorting husked ears of corn. *Lower:* Inspecting and sorting cut corn. (*Eugene Fruit Growers' Cannery, Eugene, Ore.*)

water in a closed shaker-mixer, similar in operation to canned-paint shakers seen in paint stores.

The amount of water varies with the maturity of the corn, more being needed for mature than for succulent young tender corn. Bitting states that under average conditions about 1 gal. of water to each 4 gal. of corn is a normal ratio. The amount of sugar added varies between wide limits, according to the preference of various canners and distributors, the quality grade of the corn, and its maturity. More is used for Fancy than for Stand-

ard quality. Or the sugar and salt may be first made up in water, to form a sweetened brine which may be conveniently measured and added to the batch in the mixer.

According to Bitting, if the brine method is used, an average composition would be 50 to 80 lb. of sugar and 15 to 25 lb. of salt per 100 gal. of brine, more sugar for Fancy grade and less for Standard. With young tender corn corn about 20 gal. of the brine is added to 80 gal. of corn, more brine to mature corn.

The amount of starch added is only sufficient to give a desirable consistency, more being needed for young tender corn than for the more mature, as it has less starch of its own. The starch must be premixed with water before addition in order to prevent formation of lumps.

The mixture is heated by direct steam admitted by perforated pipes in the bottom of the tank. The corn is continuously mixed. The temperature is brought to 160°F. under automatic control. There are usually two batch mixers so that one may be heated while the other is being filled. The mix must not be held too long, or curdling is apt to occur.

The hot mixture is pumped to a second blender where it is heated to 190°F. long enough to gelatinize the added starch and give a uniform mixture.

Next it is pumped to a De Zurick automatic consistency controller. This consists of a stainless-steel cylindrical tank in which a suspended agitator in the corn mix is turned by a small motor. The mix exerts a torque on the agitator in proportion to its viscosity or consistency, the thicker the consistency the greater the torque. If this exceeds a predetermined value, a valve is opened and enough hot water is added automatically to reduce the consistency to the desired level.

From the De Zurick machine the hot mix is pumped to a holding tank, where it is heated to 200°F. and flows by gravity through a desilker to the filling machine. It is filled scalding hot into C-enamel-lined cans by an automatic filling machine similar to that previously described for whole-kernel corn, except that the briner is not used. In the Northwest the 303 size can, instead of the No. 2, is commonly used for cream-style corn for family use.

Processing Cream-style Corn. Most canned cream-style corn is processed in still retorts of either the vertical or horizontal type.

Several Northwest plants use the National Canners Association temperatures and times, which are given on page 253.

It will be observed that the initial temperature of the can contents has a great effect on time required for processing. Cream-style corn conducts heat very slowly because gelatinized starch practically prevents convection currents in the canned product and thus greatly decreases the rate of heat penetration. The continuous method of processing nonacid foods is dis-

Can name	Dimensions	Initial temperature, °F.	240°F., min.	Time at:	
				245°F., min.	250°F., min.
No. 1 Picnic..........	211 × 400	140	80	70	60
	211 × 400	180	70	60	50
No. 303.............	303 × 406	140	95	85	75
	303 × 406	180	85	75	65
No. 2...............	307 × 409	140	105	95	85
	307 × 409	180	90	80	70
No. 3 Cylinder........	404 × 700	140	160	145	130
	404 × 700	180	135	120	105
No. 10...............	603 × 700	140	220	205	195
	603 × 700	180	180	165	155

cussed also in the chapter on processing. It results in much less heat damage to color and flavor than occurs with the much longer processing periods in still retorts.

Kueneman of the J. R. Simplot Company, Caldwell, Idaho, says close control of consistency is essential. This requires that about 50 per cent of the mix be kernel tops. A special cornstarch, free of thermophile spores, is added to give the desired consistency. The initial temperature must be 180°F. or higher. The starch is added at the batch mixer as a slurry; the sugar, salt, and water as a sweetened brine. The starch and sugar-salt brine are placed in the batch mixer first, then the corn. The batch of 100 gal. is heated under constant agitation to 180°F. for about 10 min. It is then heated in a blender mixer to 190 to 200°F., which completes the cooking of the starch, "averages up" the consistency, and removes most of the occluded air and gas, thus reducing the tendency of cream-style corn to foam during filling into cans. It is then brought to desired consistency in a De Zurick apparatus.

In filling the cans a head space of at least ¼ in. is necessary at time of sealing to give a "bubble" in the can contents, essential to rapid and uniform heating in the retort. In a high-speed, continuous agitating FMC retort, 303 size cans are heated at 275°F. for 12 min. A minimum initial temperature of 180°F. for can contents is specified.

An FMC consistometer is used to measure the consistency of the mix in the batch mixer and blenders, the desired reading being 90 to 100 on this instrument. Frequently cans that have been sterilized are opened, and the consistency of the product measured. Other canneries in the Northwest

also use this instrument in ascertaining and controlling the consistency of their canned cream-style corn.

Smooth-walled No. 10 cans should not be filled too hot or they will panel after retorting and cooling. Beaded No. 10 cans are preferable, since they resist paneling.

Cooling Canned Corn. Canned corn cools slowly because of its high viscosity; especially is this true of cream-style corn. If not cooled sufficiently, viz., to 95 to 100°F. at the center of the can, flat souring by thermophilic bacteria may occur or the color and flavor may be damaged.

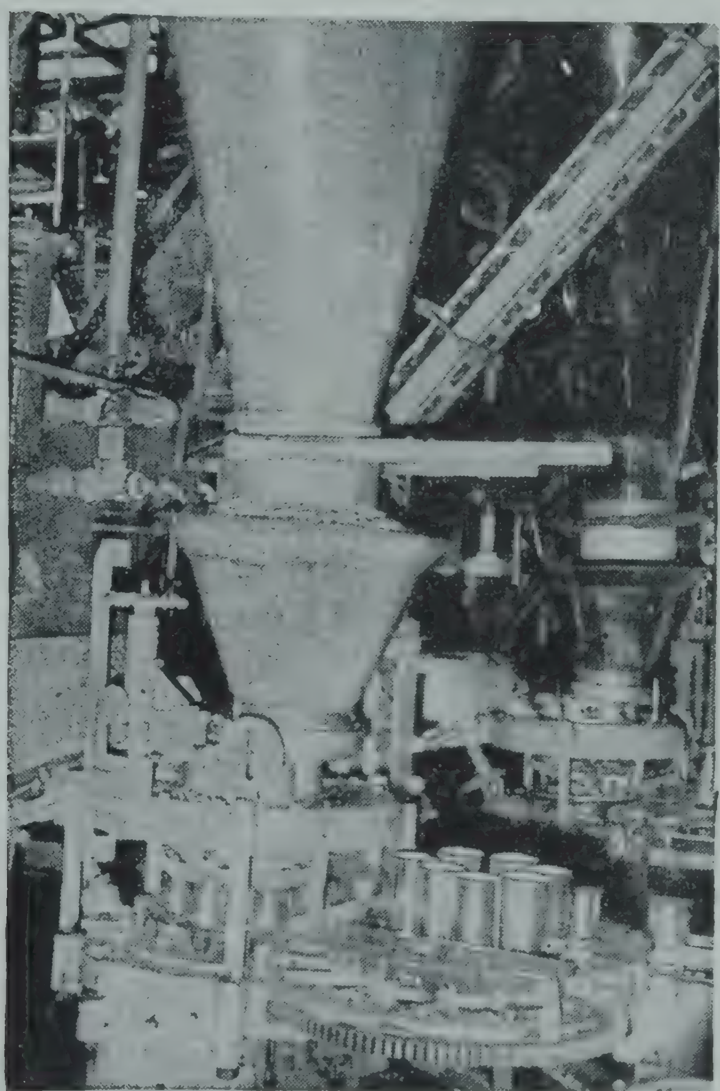


Fig. 51. Can filler for peas and corn. Oregon.

In one plant in the Pacific Northwest cream-style corn retorted in No. 10 cans in a still retort is cooled under pressure in the retort with cold water for about 60 min. and then in cold water at atmospheric pressure for an additional 30 to 60 min. Smaller cans are usually partially cooled in the retort and then cooled additionally to 95 to 100°F. (at the center of the cans) by conveying them through a long tank of running cold water. While whole-kernel corn cools more rapidly than the cream-style, it also is often given additional cooling in water at atmospheric pressure after preliminary cooling in the retort.

Standards for Canned Corn. The U.S.D.A. standards for canned corn are as follows:

U.S. Grade A Fancy Cream Style corn must be prepared from young, tender sweet corn or corn of similar varietal characteristics. The color is bright, and the product possesses a heavy creamlike consistency. It is practically free from defects such as presence of silks, husks, particles of cob, off-colored kernels, etc. The kernels have been cut neatly and uniformly from the cob and are in the early cream stage of maturity. The product possesses a flavor typical of succulent young corn and scores not less than 90 points by the U.S.D.A. canned-corn scoring system.

U.S. Grade B (Extra Standard or Choice) canned cream-style corn has similar specifications to those of Grade A except that the word "reasonably" replaces "practically," the corn is in the cream stage, and scores 75 to 89 points.

U.S. Grade C (Standard) cream-style corn is of somewhat poorer quality than Grade B, yet must be palatable, fairly free from defects, and score 60 to 74 points.

Off-grade canned corn is that which scores less than 60.

As previously mentioned, consistency in production is controlled by the De Zurick machine. In the laboratory consistency is measured in some plants by a Stormer viscosimeter; in others by an FMC consistometer. For cream-style corn the Federal scoring system is as follows:

	Points
Color	10
Consistency	20
Absence of defects	20
Maturity and tenderness	30
Flavor	20
Total	100

The scoring system for whole-kernel canned corn is as follows:

	Points
Color	10
Absence of defects	20
Cut	10
Maturity and tenderness	40
Flavor	20
Total	100

Detailed directions for arriving at scores for each attribute are given in the printed specifications obtainable from the U.S.D.A., Agricultural Marketing Administration. See these for whole-kernel specifications.

Cans of corn are considered slack-filled if the head space, measured from the top of the product to the underside of the lid, exceeds 10 per cent of the total inside height of the can. Cans that are slack-filled must be labeled "Below Standard in Fill."

BEETS
(Beta vulgaris)

According to the National Canners Association statistics recent total annual packs of canned beets have been as follows: 3,719,000 cases in 1940; 9,140,000 cases in 1945; 8,153,000 cases in 1950; and 10,121,000 cases in 1956. The pack in the Pacific Northwest in recent years has ranged from 871,000 to 1,405,629 cases. Wisconsin at present is the largest packer of canned beets, with annual output ranging from 2,519,892 to 3,296,658 cases per year.

Harvesting. The seed is planted usually in the spring, preferably in friable rather than clayey soil, as the former tends to produce the globular shaped beets preferred for canning. The color of the flesh must be deep red and without prominent light-colored rings. The texture should be tender, not fibrous or tough. The Detroit Dark Red variety is reported to be a good variety for canning.

The beets are harvested in the field by running a plow or deep-set special cultivator along the row to loosen the roots. They are topped in the field by special machine; in one type rollers revolving toward each other catch and pull off the tops without damaging the beets. Probably the mechanical harvester and topper used for harvesting sugar beets could be used.

In the Pacific Northwest the beets are delivered to the cannery by dump truck in bulk and dumped into a large bin below the floor or on a concrete slab outside the cannery.

Washing. In one large plant they are then washed very thoroughly in a rotary-drum spray washer. If much claylike soil is adhering to the beets they are soaked in a tank of water before washing.

Grading and Peeling. They are graded roughly into three size classes by a rod-and-reel sizer, the rods running lengthwise of the grader and diverging to give three size groups. They are then peeled by a two-stage procedure in which they are heated sufficiently to loosen the skin without overcooking the flesh and are then peeled in an abrasion peeler, in this case an Urschel machine.

They are inspected and trimmed by hand to remove any remaining crowns and roots and defective sections. Culls are discarded. They are again run through the abrasion peeler.

They are again graded by machine for size, the smallest beets for canning whole, the medium sizes for slicing, and the largest sizes for dicing or cutting into julienne (shoestring) strips. The diced and julienne cuts are washed under sprays to remove fines. Bitting states that beets of $1\frac{13}{16}$ in. or less diameter are suitable for canning whole; those between this diameter and $2\frac{3}{4}$ in. for slicing; and those above this size but less than $3\frac{1}{2}$ in. for dicing or julienne-cut pieces. However, commercial practice varies in this regard.

The beets are canned in enamel-lined cans in order to prevent bleaching of the color and blackening from reaction with the iron of the tin plate. For this reason also the peeled beets should not be handled in or with plain iron or steel equipment.

In another plant the beets are washed, then heated in a high-pressure steam peeler in a closed chamber for a short time and released to the open atmosphere. The skins "explode" off the beets or are loosened to the extent that they are easily removed in a rotary drum washer under heavy sprays of water. They are then inspected, sorted, and trimmed from a slowly moving belt, size-graded, and then treated as described earlier in this sec-

tion. According to Bitting and others, the beets are peeled in some canneries by first heating in a retort at about 220°F. to loosen the skins and are then peeled by an abrasion peeler.

Canning. The sliced, diced, and julienned beets may be filled by machine or hand-pack filler, and the whole beets by hand or hand-pack filler. A light brine which may or may not contain a small amount of sugar is added to fill the cans, which are then exhausted in steam, sealed, and retorted. Exhausting may be omitted, and the cans sealed by the steam-flow method. The 303 size can is used extensively in the Pacific Northwest.

Processing. In one plant in that area the 303 cans are processed in a continuous agitating FMC retort at 240°F. for 22 min. and cooled in a two-stage continuous cooler for 12 min. Number 10 cans are given 33 min. at 240°F. in the same type of retort and 19 min. cooling. In another plant the National Canners Association processes are given in still retorts. These are 30 min. at 240°F. for No. 2½ and smaller cans if sealed at or above 140°F.; 35 min. if sealed cold; for No. 10 cans the process is 40 min. at 240°F. if not sliced and if initial temperature is above 140°F.; for sliced, the time is increased to 45 min. Sliced beets are also packed in glass jars in in a light sirup containing vinegar and processed at 238°F. for 28 min.

OKRA
(Hibiscus esculentum)

Okra is used principally for soups and is a staple garden crop of the Southern states, where it is known in some localities as "gumbo." The pods resemble peppers in appearance and are rich in gums and probably pectin. The pods should be picked while still tender and before they have become fibrous and tough.

The pods may be blanched 1½ to 2 min. in water. The butts should be cut off and discarded, and the pod should be cut into sections crosswise with a string bean cutter. The pods may also be cut in cross sections and canned without blanching. The National Canners Association recommends a process of 30 min. at 240°F. for No. 2 cans and 35 min. for No. 2½ cans of okra, if the initial temperature is at or above 140°F.

PEAS
(Pisum sativum)

Peas were brought to America with the first immigrants and are now grown practically everywhere in the United States as a home-garden crop and for the fresh market, but they are grown even more extensively for canning.

Size of Industry. The pack of canned peas has been less than that of corn in recent years. The canned product is relatively low in price to the consumer and is a food of attractive flavor and high nutritive value rather than a luxury.

The pack has increased from about 800,000 cases in 1885 to 33,094,000 cases in 1956. As with corn, the production of canned peas has varied greatly from year to year according to whether the preceding year was one of under- or oversupply. This condition is shown in Table 23.

TABLE 23. CANNED-PEA PRODUCTION

Total production in the United States*		1954 production by states for 1954	
Year	Cases, actual	State	Cases on basis of 24/2s
1906	4,574,608	Maine and New York	782,688
1907	5,885,064	Maryland	876,811
1908	5,577,000	Delaware and New Jersey	122,517
1909	5,048,000	Pennsylvania	857,124
1910	4,137,000	Ohio	89,536
1912	7,307,000	Indiana	155,998
1913	8,770,000	Illinois	2,354,107
1915	9,272,000	Michigan	139,420
1916	6,686,000	Wisconsin	9,839,515
1918	11,063,156	Minnesota	2,943,707
1919	8,685,000	Idaho and Utah	655,811
1920	12,317,000	Washington and Oregon	4,355,595
1930	22,035,000	Other states	797,875
1933	12,892,000		
1935	24,698,000	Total cases	23,950,704
1940	25,460,000		
1943	33,826,500		
1945	38,556,000		
1950	32,725,536		
1952	29,446,277		
1956	33,094,000		

* Production in column 2 of the table is reported in terms of actual cases of all sizes, while in column 4 these have been converted into the equivalent numbers of cases of 24 No. 2 cans each.

SOURCE: After Canning Trade Almanac and National Canners Association.

When high prices for peas prevail, planting and canning are stimulated, often to the point of overproduction. Provided the peas are available for

canning, the capacity of present pea canneries is more than sufficient to meet the normal demand.

At the present time prices and production of both canned peas and corn are subject to rather wide fluctuation. Also, there is need for devising a process of canning which will retain more of the color and flavor of the fresh peas. Canned peas have a greenish-yellow color, in contrast with the bright green color of cooked fresh peas and frozen peas. These last are giving considerable competition by their fresher flavor as well as by their more attractive color.

Historical Note. At first peas were grown garden-fashion and picked and hulled by hand. Excessive labor costs limited the output of the canneries and made the price of the product high.

Numerous mechanical hulling machines have been invented, but most of them were failures, since they were attempts to imitate mechanically the pressure exerted on the pods by the fingers. Rubber rolls, revolving disks, and other machines dependent upon pressure were of very limited capacity, did not hull perfectly, and bruised the peas.

In 1883 Madame Faure in France invented a machine which hulled the peas mechanically by impact. Paddles revolving in a screen cylinder broke open the pods and the peas were separated by screening. Her invention was described in *La Nature*, Paris, in 1885, and a translation of her article appeared in the *Scientific American*, June 6, 1885. Shortly thereafter, a similar machine was built in America, was proved successful at Baltimore, and was rapidly adopted by commercial canneries.

Madame Faure's machine did the work of 100 hullers; the early American machines were somewhat larger. Scott and Chisholm were prominent in developing pea-hulling machines in America.

According to R. P. Scott, in the season of 1886 all peas were hulled by hand; in 1887 an appreciable quantity were hulled by machinery, and in 1888 one-half of the output was so hulled.

The invention of the impact huller made it possible to move canneries away from the cities to the thinly populated producing sections, thereby greatly reducing costs of production.

In 1890 to 1892 the hulling machine was so modified that it became possible to thresh the peas from the pods on vines that had been cut with a mower. Previous to this it was necessary to pick the pods by hand. This advance was of nearly equal importance with Madame Faure's invention.

Today peas are grown as a field crop by tractor cultivation, harvested by mowers or pea harvesters, hauled by truck to the viner, hulled mechanically, and taken at once to the cannery, where they pass mechanically and more or less automatically through the operations of cleaning, blanching, filling, sterilizing, and cooling.

Climatic Requirements. A cool summer climate with frequent rains or cloudy or foggy weather produces peas that are tender, sweet, and of good color. Wisconsin is the premier pea-producing state, largely because of the favorable climatic and soil conditions. Washington and Oregon, however, are becoming close competitors.

At present New York, Minnesota, the Pacific Northwest, and Wisconsin furnish 50 per cent or more of the entire pack, although Utah and the uplands of Colorado are also very suitable for peas.

Varieties. Field peas have been classified as a different species from garden peas, but this distinction is being abandoned. Formerly field peas were classified as *Pisum arvense* and garden peas as *P. sativum.* At present both are classified as *P. sativum.*

For canning purposes, Shoemaker lists the following requirements: (1) The variety must be productive, a requirement that excludes dwarf types and includes the quality of hardiness. (2) All plants must ripen uniformly. (3) All pods on each vine must be in usable condition at one time; i.e., none must be too ripe or too immature. This requirement excludes varieties with too great length of vine. Bush vines, not climbing vines, are used. (4) The peas must remain green after processing, which eliminates yellow-seeded varieties. (5) High quality, i.e., good flavor, texture, and small size, is necessary.

The viner has made requirements 2 and 3 important. When the pods were gathered and hulled by hand, uniformity in ripening was not so necessary.

Peas for canning purposes are of two types, viz., the early smooth-seeded varieties and the later sweet wrinkled-seeded varieties. The latter are of better flavor but often do not produce so heavily as the smooth-seeded types. The words "smooth" and "wrinkled" apply to the ripe, dry peas; when green all are smooth. The most important smooth-seeded variety is the Alaska, and the most widely used wrinkled-seeded varieties are the Perfection, Horsford Market Garden, Advancer, and Admiral. Other improved varieties are used also.

The Alaska is said to be a favorite with Eastern United States canners because it is hardier and a more reliable producer than most of the wrinkled varieties. This variety ripens early and retains its color well in processing. Popular varieties in the Middle West are Early Perfection, Prince of Wales, and Green Giant s-537. In Oregon and Washington the Perfection is the principal variety used for canning and the Dark Skinned Perfection for freezing. The Green Giant Company uses its own selection.

Harvesting. The time of harvesting is determined largely by the appearance of the pods, which should be swollen and well filled with young succulent peas that change in color from dark to light green.

The fields should be inspected before harvesting to remove vines of "off type."

The cannery agent sets the date of harvesting, and frequent inspection is necessary to make certain that the peas do not pass prime condition and become overmature.

An ordinary mower, equipped with vine-lifting guards attached to the

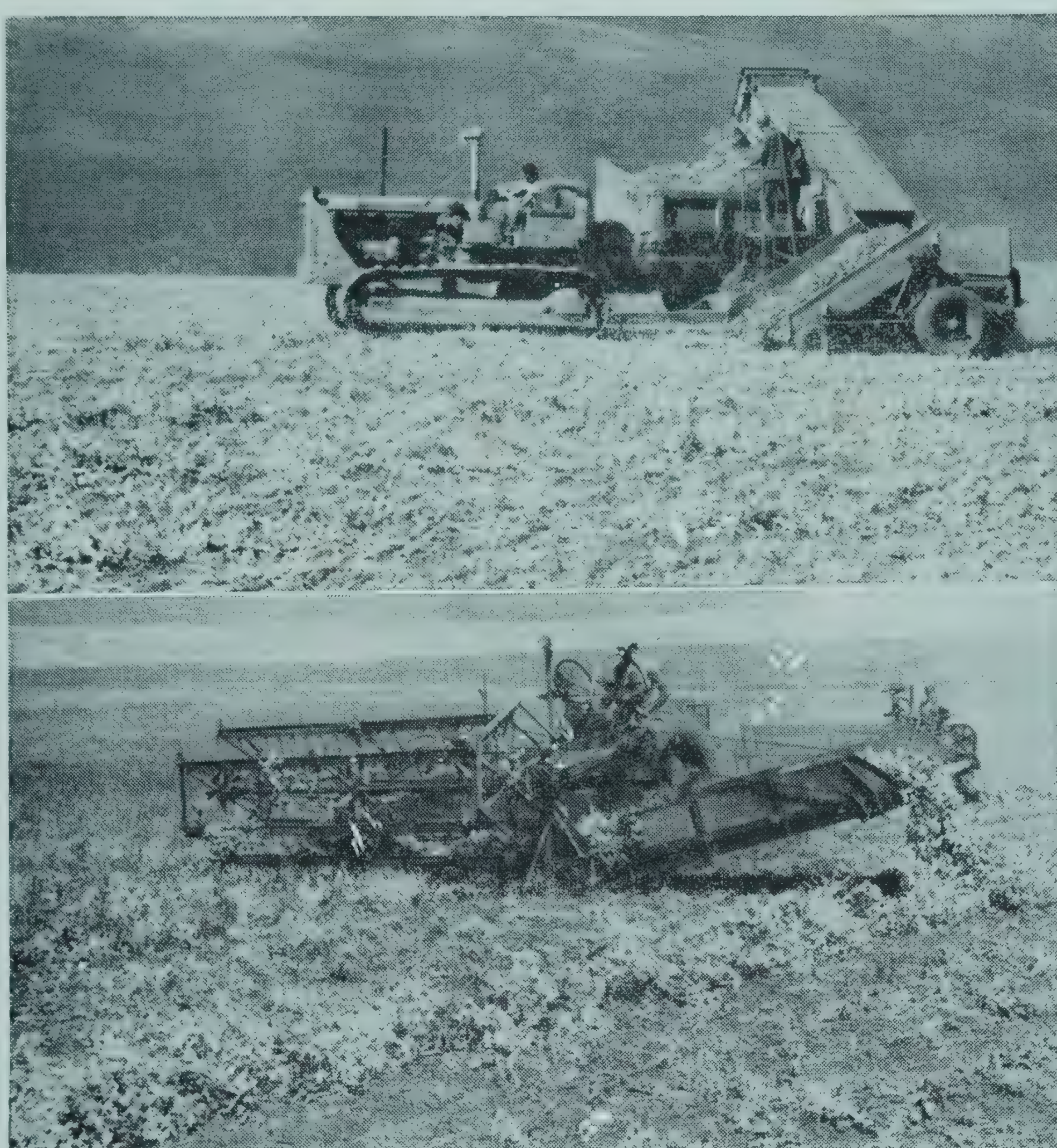


FIG. 52. *Upper:* Loading vines into truck. *Lower:* Swather at work mowing pea vines and windrowing them. Oregon.

cutter bar and a swather that bunches the vines in a neat windrow, can be used. The vines may be loaded direct from the windrow into trucks, or the rows may be bunched with a rake. Automatic loaders drawn by a tractor are generally used to load the trucks. Harvesters that cut and load the vines simultaneously without windrowing are also available. They are similar to a wheat "header" in operation. In the Pacific Northwest a "swather," equipped with a cutter bar, reel to force the vines into the cutter bar, and a draper to deposit the vines in windrows, is used. It is followed by an automatic truck loader (Figure 52).

To avoid wilting, it is desirable to cut the vines in the morning or evening rather than in the middle of the day. Delay in vining results in deterioration in quality and may permit loss of sugar, sweating, and fermentation.

Vining. Most of the shelling or vining is done at so-called "vining stations" located in the fields, thereby avoiding long haulage of the vines. The great disadvantage of this method is that the shelled peas deteriorate during the several hours that usually elapse between vining and canning. This delay is avoided if the viners are located at the cannery. At the viner considerable juice from the pods collects on the peas and dries on their surface, with resultant deterioration in flavor. The dried juice is very difficult to remove. The inferior flavor of some canned peas can be traced to these conditions. The Food Machinery Corporation Stericooler gives promise of checking deterioration after vining.

The vining machine consists of a perforated metal cylinder, inside which are beaters on a central shaft. The cylinder revolves slowly, while the beaters revolve rapidly. The peas are hulled by impact with the beaters and fall through the openings in the cylinder. The vines are carried through the cylinder and are delivered to a conveyer, which delivers them to a truck or to a silo. The beaters are pitched at such an angle that the vines are carried through the cylinder; the speed of the beaters and the pitch determine the time the vines remain in the viner. The speed of rotation is varied according to the length of the vines and the maturity and toughness of the pods. The peas drop through the perforated cylinder onto a canvas belt moving slowly upward, to which leaves and pieces of pod stick while the peas roll down the belt into hoppers or lug boxes (Figure 53).

One viner is required for each 100 acres under average conditions. According to recommendations of the A. K. Robbins Machinery Company, three viners will supply peas for one cleaner, one blancher, one filler, two closing machines, and five 40- by 72-in. vertical retorts. Each viner can do the work of 200 persons shelling by hand.

In hot weather it is essential to transport the shelled peas immediately to the cannery in order to forestall bacterial spoilage. Crushed ice may be added to the boxes of peas if delay in canning occurs.

Several canneries in Oregon and Washington bring the vines by truck to viners located adjacent to the cannery, in two cases the vining stations being located on a steep slope above the cannery in order that the peas after vining can be carried in water by gravity into the cannery. Within a few minutes after vining the peas are in the cans. Most canners in that region, however, have their vining stations in the fields. The viners are portable and drawn by truck or tractor from one field to the next as the season progresses. The shelled peas are collected at the viners in these cases in 50-lb. lug boxes, although the boxes are not filled completely. They are placed on pallets, and the loaded pallets placed on a truck by fork-lift

truck for immediate transport to the cannery. Normally not more than 4 hr. elapses between vining in the field and canning of the peas. The viners in the field are fed by pitchfork, one man to each viner. The stationary viners used at the canneries are fed by a small and very specially built derrick fork, operated by motor. By its use one man easily feeds two viners. It is supplemented by a device on the vine elevator that gives an even flow of vines into the viner. Both devices are made by the Key Equipment Company of Milton-Freewater, Oregon (Figure 53).

The vines are in some cases spread in the field to dry and are then baled for use as hay; or they may be stacked to undergo fermentation and curing as ensilage; or they may be spread and later disked or plowed under as a soil improver. At one of the large canneries in Milton, Oregon, at which the vining is done at the cannery, the vines fall directly from the viner into a very large pit silo (a wide trench several hundred feet long). A track-laying tractor travels back and forth on the vines to compact them. Later the ensilage is fed with concentrates such as cottonseed meal to beef cattle in a field near the cannery. Some vines are also fed fresh to livestock.

In eastern Washington and Oregon the author was informed that under normal crop conditions about 5 tons of vines yield a ton of shelled peas.

In that area the peas are grown on the slopes, often steep, of the foothills of the Blue Mountains. Peas are first planted early in the spring on the level land at the foot of the mountains, and then on progressively later dates at successive, higher elevations, some being planted at as high as 3,300- to 3,500-ft. elevation. This program gives a long season, often 6 weeks or longer. The climate and soil combine to grow peas of high canning quality. The vines are grown without irrigation.

Yields. The yield of shelled peas varies greatly with the locality and growing conditions. For example, in a normal year the yield in eastern Washington and Oregon is said to be about 2,200 lb. per acre, whereas in 1955 it was only 1,000 to 1,200 lb. because of a long period of drought in late spring and early summer. Bitting mentions a yield from Advancer variety peas grown experimentally of 7,581 lb. per acre. Records taken several years ago showed an average yield during a 4-year period of 1,800 lb. per acre for the United States as a whole.

Cleaning. At the cannery the shelled peas from the viner stations in the fields are emptied on to a conveyer that transports them to what might be termed the dry-cleaning department. They first pass in most plants over a broad, vibrating screen known as a scalper screen; the peas drop through the screen, and leaves, clods, pods, and other trash of larger diameter than the peas pass over the end of the screen. At canneries where the peas are vined at the cannery the shelled peas go directly from the viner over the scalper screen.

Next they are cleaned in a clipper cleaner, which operates on the same

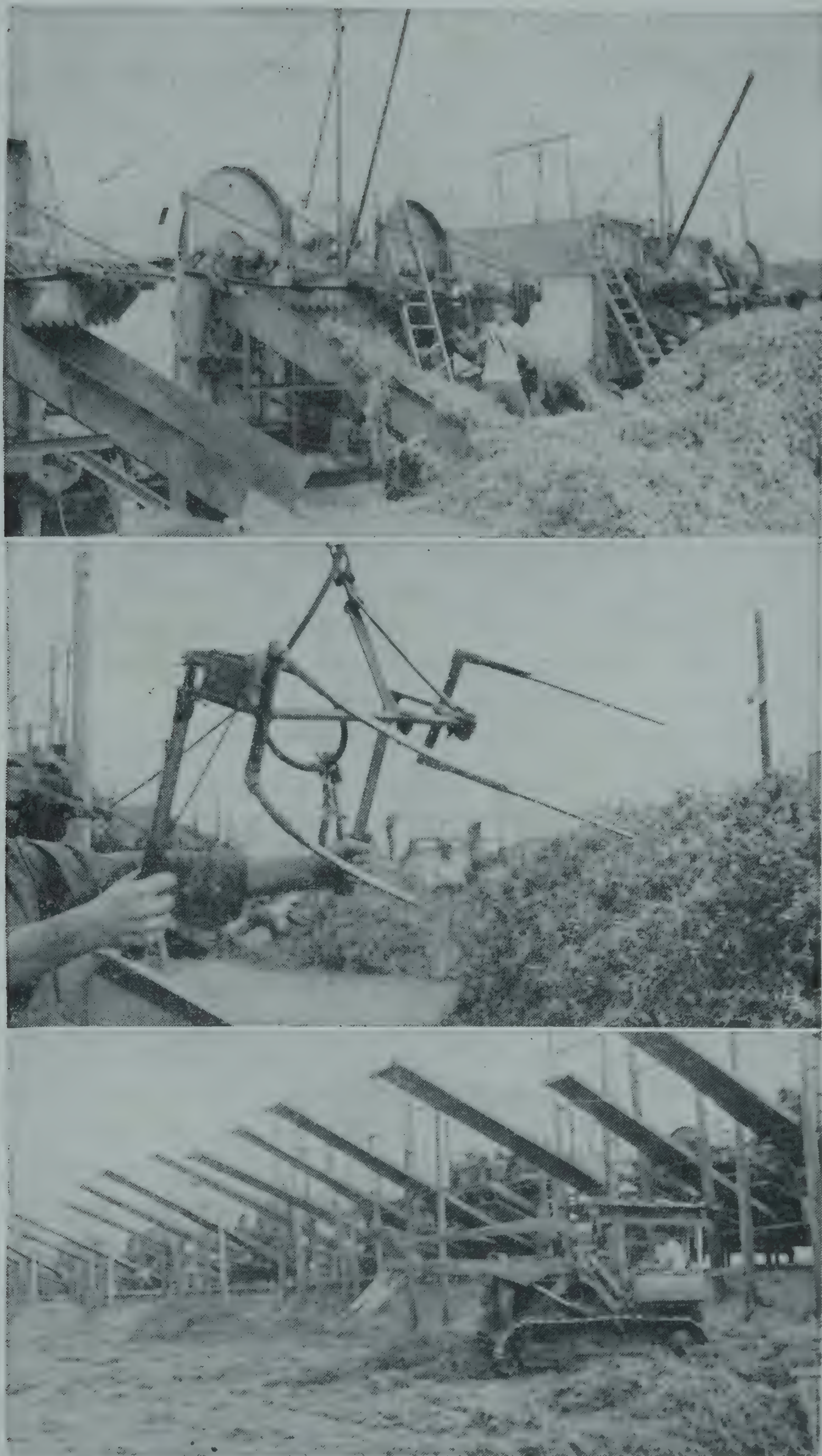


Fig. 53. *Top:* Pea viners being fed by small derrick fork; one man feeds two viners. *Center:* Close-up of fork. *Bottom:* Pit silo with waste vines from viners. Note track-layer tractor used to compact vines. (*Umatilla Canning Co., Milton-Freewater, Ore.*)

principles as a grain-cleaning mill that many farmers use in cleaning wheat, barley, and oats for use as seed. A strong blast of air from a fan blows light trash away, and screens remove coarser waste material. The peas fall through the screens and are conveyed to the next cleaning station, which may be termed the wet-cleaning department. A machine first devised by Neubert and Veldhius, agricultural research workers in Washington state, in 1945, known as a froth flotation separator, or flotation separator, is used. Until its invention and adoption such undesirable waste materials as nightshade berries, hulls of peas broken in vining, weed burrs, and other similar "trash" were picked out by hand from a moving belt. The flotation separator operates on the principle of difference in wettability of peas compared with that of nightshade berries, thistle heads, weed seeds, etc., in a frothy mixture of small air bubbles, water, a colorless, tasteless light mineral oil, and a special soap of high detergent power. The nightshade berries and other weed seeds and fragments, also pea hulls, because of the difference in wettability compared with that of the whole peas, collect many small bubbles of air from the frothy mixture and thereby become lighter than the peas and float; the peas sink.

In cannery operation of the separator the peas are delivered by conveyer into stainless-steel tanks of water to which has been added a special soap in the form of a paste and a highly refined, colorless mineral oil. In several canneries in eastern Oregon the soap was obtained in 1955 from Proctor and Gamble Company under the name of Orvus W. A. Paste. The oil was furnished by the Key Equipment Company of Milton-Freewater, Oregon, the company which builds the flotation separator and essential accessory equipment; or the oil was obtainable in 1955 also from the Union Oil Company. The separation tank is in the form of two cones, one inverted and the other upright, with a cylindrical portion between the cones. A special pump in the bottom of the machine violently aerates and circulates the liquid, converting it into a frothy mixture. As the peas drop to the bottom of the lower cone they are picked up by a pump and delivered to a squirrel-cage spray washer in which any adhering oil, etc., are thoroughly removed. The trash floats to the surface and is carried away in the overflow from the upper cone.

See Figure 56 for the appearance of a typical flotation separator such as used in pea canneries and freezing plants in the Pacific Northwest.

Size Grading. In some plants the peas are graded for size after flotation-separator treatment; in others size grading is done before flotation separation. Size grading is usually done by passing the peas through a long slowly revolving screen cylinder or through a series of nested or parallel screens; in either case the screens have holes of the diameters given below. In some graders the smallest peas are removed first; in others the largest sizes are removed first. An important requirement for satisfactory size grading is

that the grader be fed at a uniform rate and not loaded beyond its capacity. If overloaded, many of the peas that should pass through the screen are carried over with the larger sizes. Flat size-grading screens have been built and are in use but are said to be less satisfactory than the cylindrical screens.

The screen sizes are as follows:

Size number and name	*Screen diameter, in.*
No. 1—Petite	$9/32$
No. 2—Extra Sifted	$10/32$
No. 3—Sifted	$11/32$
No. 4—Early June	$12/32$
No. 5—Marrowfats	$13/32$
No. 6—Telephone	Larger than $13/32$

In the trade the size grades are usually designated by number, as 1, 2, 3, etc., rather than the older terms Petite, Sifted, etc. Also frequently two or more sizes are combined into a single grade; e.g., the numbers 1 and 2 and the 4 and 5 may be combined.

The No. 1 size peas fall through the $9/32$-in. screen, and the No. 7 size passes over the $13/32$-in. screen. In many plants the No. 7 peas are discarded or fed to livestock since they are apt to be overmature. Toward the end of the season one cannery in the Pacific Northwest in 1955 at the time of our visit was not size-grading the peas because they were all of approximately the same size; however, it separated out the overmature peas in its brine-flotation quality grader.

In the preparation of peas for freezing it is customary to bypass the size grader and pack all sizes together as garden run. Or the No. 7 size peas is removed by grader and discarded or fed to livestock.

In some plants the peas are sorted from a belt after size grading, but this is not usually done in eastern Washington and Oregon until after blanching.

The peas are pumped or flumed to the blanching department after size grading. See also Chapter 4 on grading.

Blanching. Blanching of peas has several purposes. One of the most important is that of cleansing the surface of the peas by softening and dissolving the dried coating of viner juice. This is juice from the pods and leaves that wets the peas during vining. It may contain considerable imbedded dust and other debris, and if too long a time elapses between vining and canning, it may develop a large population of bacteria. The hot water used in blanching removes most of this coating. Blanching tends to remove a slight raw taste and odor characteristic of shelled peas that have stood for some time. It also removes most of the air and other gases entrapped or dissolved in the pea tissues; unless removed before canning they are apt to lower the vacuum in the cans. Another objective of blanching is to swell and soften the peas so that a more uniform fill of the cans and more

uniform texture of the canned product are attained. Blanching probably does not "set" the color. Young tender peas require much less blanching than do rather mature peas.

The blancher in most common use consists of an outer heavy steel drum which contains heated water; in this drum is a revolving perforated, galvanized steel drum inside of which and welded to its walls is a spiral several

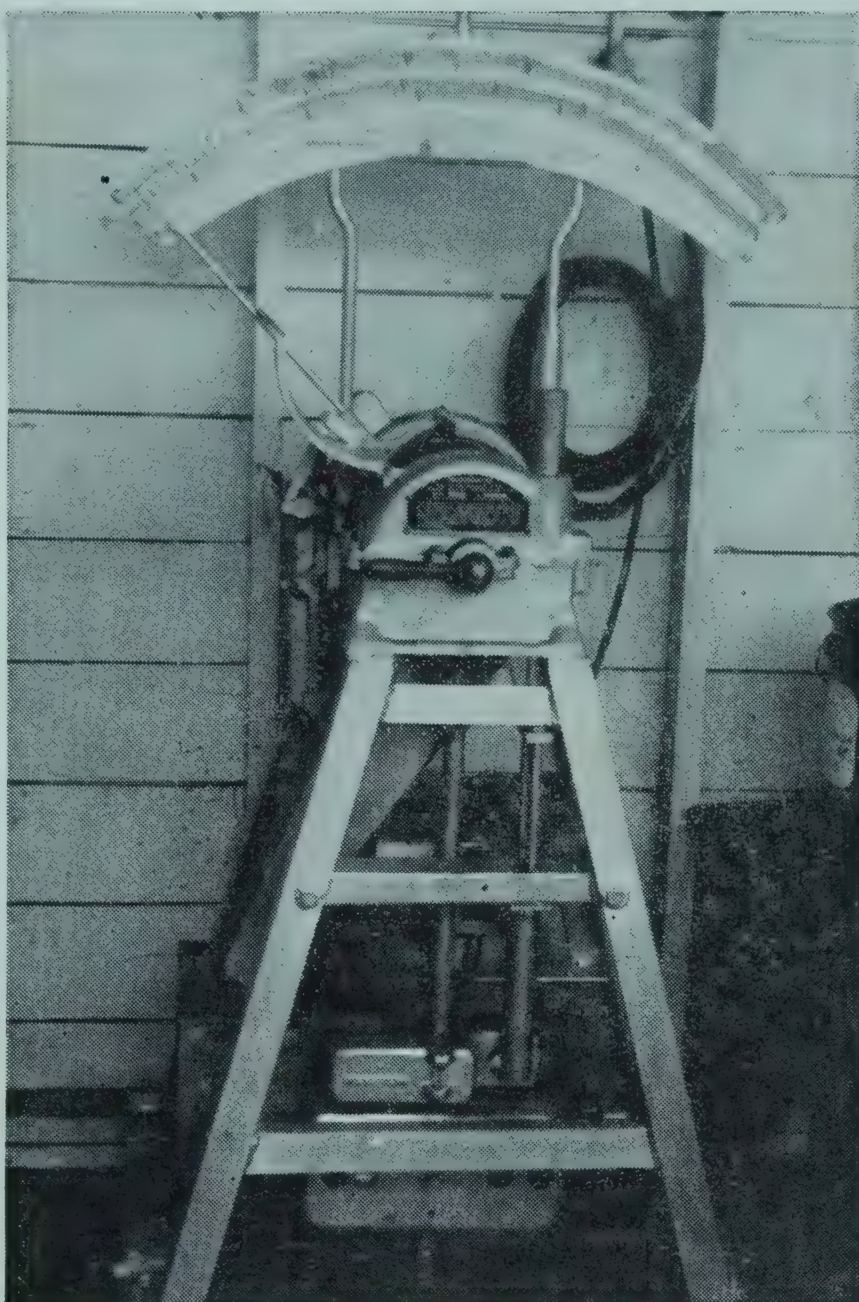


FIG. 54. Tenderometer for testing maturity of peas. Walla Walla, Washington.

inches deep and made of sheet metal. The peas are fed into one end of the revolving drum, and the spiral carries them through the hot water in the outer drum. The water is heated by steam supplied by perforated pipes, and the temperature is usually automatically controlled. Water is fed continuously into the discharge end of the blancher so that the peas will encounter water of increasing freshness as they pass through the machine. In some blanchers a rotary screen is installed beyond the outlet spout so that the peas may be spray-washed as they emerge after blanching. For the latest type of blancher for peas see Figure 13.

Blanching temperature varies in different pea-canning districts but is usually below the boiling point. In the Pacific Northwest a blanch of 3 min.

at 190 to 200°F. is common for peas of average maturity and size. If they are fairly mature, it may be increased to 4 to 5 min.; and if they are young and tender peas of Nos. 1 and 2 sizes, it may be shortened to 1½ min. Boiling water is seldom used because it causes undue bursting of the hulls and may soften the peas unduly, causing stoppage in the can filler. Water used for blanching should be soft because hard water containing much calcium will harden the peas. As indicated in the chapter on washing, peeling, and blanching, some of the valuable nutrient materials is lost in blanching, more in water than in steam blanching. However, steam blanching does not have as great cleansing and plumping action as the water blanch. See the section in Chapter 11 on blanchers as a source of spoilage organisms.

The blanched peas are cooled somewhat by fluming or pumping in water en route to the quality grader.

Quality Grading. This operation consists in passing the peas through a tank of brine of certain density, or two such tanks. Formerly this was done with the raw peas before blanching; at present it is usually applied to the blanched peas because much better grading is obtained with the blanched product.

In Oregon and Washington the brine is usually of 38 to 40° salometer and is maintained constantly at the desired salometer degree by an automatic recorder controller. The less mature, more tender, and succulent peas are of lower density than the more starchy, riper peas and will float in brine of this concentration, and the more mature Grade B peas will sink. The heavy B-grade peas are removed from the bottom of the brine separator continuously and are pumped or flumed to the next operation; the lighter A-grade peas are carried over in the overflow and conveyed to the next stage. Both classes are thoroughly washed immediately after brine separation in order to remove adhering brine which might cause shriveling or make the canned product too salty in taste.

Control of the salt content of the brine is attained by automatically adding saturated brine as needed; the water introduced with the peas dilutes the brine slightly, making the addition of strong brine by the controller mechanism from time to time necessary.

In some canneries a second brine separator is used to separate the B-grade peas into two quality grades. Bitting states that the brine in this second tank usually has a specific gravity such that the peas that sink in this brine are Seconds, or Substandards, and those that float are Standard, or Grade B.

Inspection and Sorting. The blanched and quality-graded peas after washing are critically inspected and sorted on a slowly moving belt. Peas of off color, splits, and any undesirable debris or trash that has gotten by previous mechanical cleaning operations are removed by experienced sorters.

Canning. The sorted peas are elevated to a hopper above the can-filling machine. They flow by gravity to a smaller cone-shaped hopper on the can-filling machine; from this small hopper the peas fall into the cups of the automatic rotary can filler. Each cup delivers into a can exactly

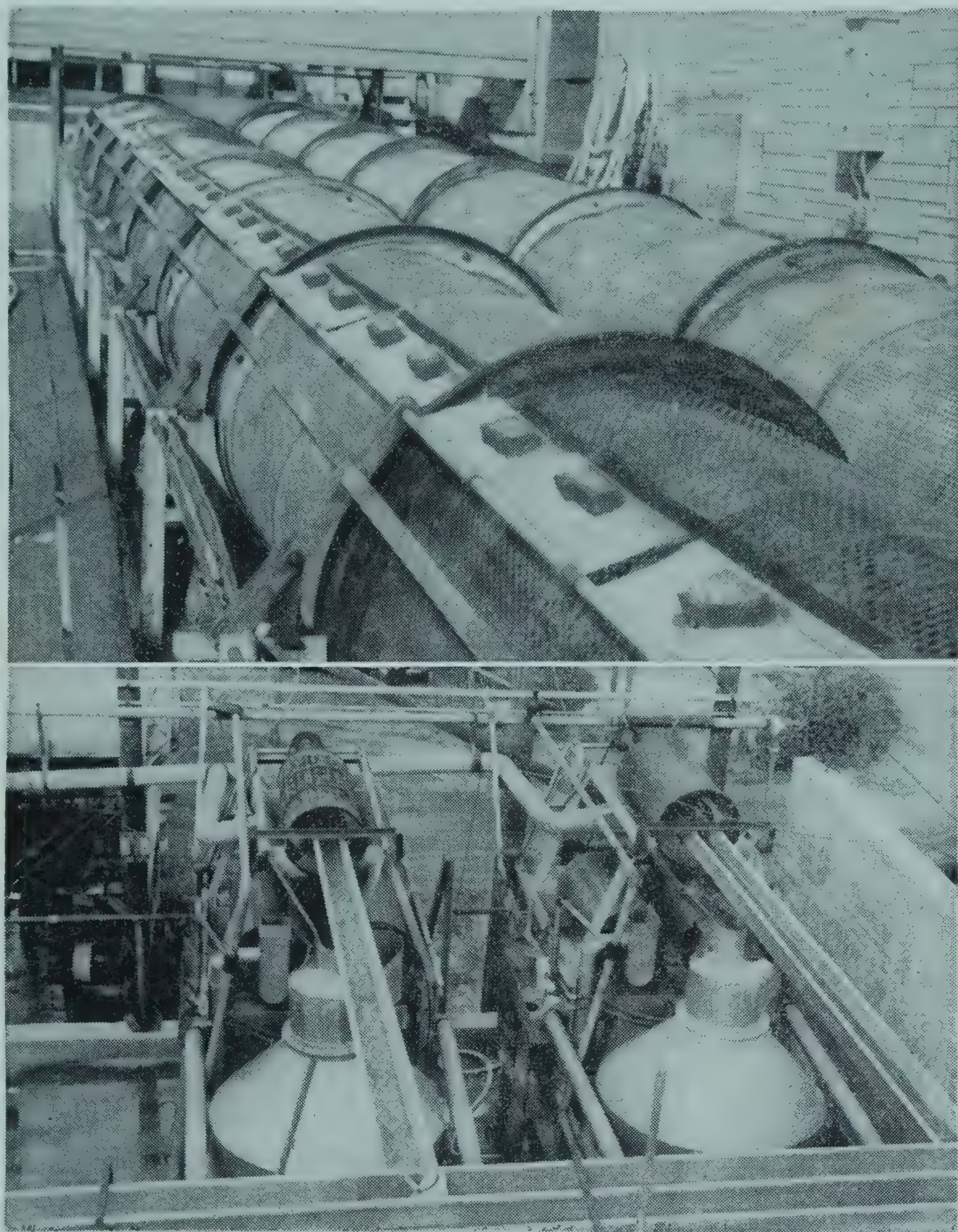


FIG. 55. *Top:* Size graders for peas. *Lower:* Revolving dewatering screens for flumed peas, and two Key flotation separators. (*Umatilla Canning Co., Milton-Freewater, Ore., and Walla Walla Canning Co., Walla Walla, Wash.*)

the desired volume, and hence the desired weight of peas. The cans are carried in a circular path around the filling platform and delivered to the briner (Figure 51).

The brine also is measured by adjustable cups, or so-called "tubes," in the same manner as previously described in the section in this chapter on the canning and brining of whole-grain corn. The brine in the Northwest is usually added at about 160°F. and drops to about 130°F. by the time the can is sealed. In these plants the cans are sealed in an atmosphere of

steam by steam-flow or steam-vac procedure; or the lid may be clinched by the can sealer on the top of the can and the can prevacuumized and sealed in vacuum, as described in the chapter on fruit canning. The aim is to obtain a vacuum in the can after retorting and cooling of about 7 to 11 in. In none of the plants visited in 1955 was an exhaust box used.

Formerly the No. 2 can was the most popular size, but in the Northwest, at least, it has been largely replaced by the 303 size. Some peas are canned in 8-oz., Picnic size, and in No. 10 cans.

Processing (Retorting). In most plants at present the canned product is retorted in vertical or large horizontal still retorts, although continuous agitating retorts are also used for the smaller cans, especially the 303 size in some canneries.

The processing times and temperatures recommended by the National Canners Association are in common use for still retorts.

These recommendations are as follows:

Can name	Dimensions	Initial temperature, °F.	Time at:		
			240°F., min.	245°F., min.	250°F., min.
No. 2 and smaller	307 × 409 and smaller	70	36	26	16
		140	35	25	15
No. 3 Cylinder	404 × 700	70	50	32	22
		140	45	30	20
No. 10	603 × 700	70	55	37	25
		140	50	35	23

Typical processes other than those of the National Canners Association in use in plants visited during the 1955 season were as follows: 17 min. at 250°F. for 303 size cans and 25 min. for No. 10 cans at this temperature; 15 min. at 250°F. for 303 size cans; 26 min. at 240°F. for 303 cans; 17 min. at 250°F. for 303 and 25 to 26 min. at the same temperature for No. 10 cans; and 15 min. at 248°F. in a continuous agitating FMC retort for 303 size cans. The other times and temperatures given in this paragraph are for still retorts.

In most pea canneries visited in 1955 the cans after processing and cooling were labeled and cased immediately or were cased unlabeled, the cases stacked on pallets, and stored in the warehouse.

Brines. Because some sugar is lost in blanching, fluming, and pumping of peas about the plant in water and because the liquid added to the can of peas dilutes the naturally occurring sugar, it is customary to add sugar to the dilute brine used in canning. The composition of the brine differs

considerably according to the preference of the canner or his distributors and with the maturity of the peas.

In one plant during the 1955 season the brine was made up of 100 gal. of water, 19 lb. of highest-quality salt, and 35 lb. of sugar (either beet or cane); in another plant it consisted of 100 gal. of water, 16 lb. of salt, and 32 lb. of sugar. Bitting has recommended 10 to 12 lb. of salt and 20 to 25 lb. of sugar per 100 gal. of water for average conditions. The salt should be as nearly free as possible of magnesium or calcium salts because these have a hardening effect and bitter taste.

Cans. In the Pacific Northwest, as well as in other regions, the cans used for peas are enamel-lined. If C-enamel is used, all danger of black specks of FeS or blackening of the tin plate by this compound is precluded.

Re-use of Water. In many canneries the supply of water is not as plentiful as the canner would desire. A comprehensive study was made of the possibility of re-using much of the water in typical pea canneries in eastern Washington and Oregon by Mercer and York of the staff of the Western National Canners Association Research Laboratory in 1952 and 1953 (see references).

They have summarized their findings as follows (1953):

(1) The re-use system should employ the counterflow principle, that is, the sequence is counter to the movement of the peas along the preparation line.

(2) Fresh water chlorinated to 5 ppm should enter the re-use system at the flume conveying peas from the gravity separators to the inspection belts.

(3) Tanks collecting the water after each re-use should be equipped with automatic valves allowing fresh water makeup for losses in volume.

(4) Provision should be made for re-chlorination of the water at the collecting tanks at a rate sufficient to satisfy the organic chlorine demand of the water and maintain a trace (0.05 to 0.10 ppm) of free residual chlorine.

(5) Chlorine determinations should be made frequently to ascertain whether any adjustment is necessary in the rate of chlorine addition.

(6) The temperature of the re-used water should be maintained below 80°F. to minimize increase in numbers of heat resistant bacteria.

(7) No recirculation of the same water within a single line operation should be permitted.

(8) Peas should be discharged from the blanchers into reels where they are cooled and washed by sprays of fresh, chlorinated water. This water is not added to the re-use system, but is wasted.

(9) Pumping of peas while still hot from the blancher should be avoided. When pumping is necessary the peas should be cooled to below 80°F.

By this procedure very great savings in the volume of water used daily have been attained.

Bitting reports that for Eastern and Middle Western canneries not less

than 5 gal. of water is required for each case of peas canned, the maximum about 25 gal. and the average about 15 gal. Thus a cannery that packs 40 tons of shelled peas, or 40,000 cases per day, would need about 600,000 gal. daily.

Quality Control. Every pea cannery maintains some form of quality control, and some in addition make use of in-plant inspection and product-quality certification of the Federal processed-food inspection service of the U.S.D.A.

Quality control begins in the fields where the plant's field men frequently inspect every field of peas under the canneries' control. The abundance of insects that damage vines and pods is checked frequently, and when the build-up reaches a certain level in Northwest fields, the vines are dusted with 5 per cent DDT dust or parathion, or both, for control of pea aphids and weevil. The dusts are applied by aeroplanes operated by pilots who are engaged in that business. Malathion dust may also be used instead of parathion. The canned product is free of dust residue since most of the insecticide is lost during the period between dusting and harvesting; more is lost during harvesting and vining, and any slight residue on the peas would be removed by the washing, blanching, pumping, and fluming operations in the cannery.

At the cannery a 25- or 30-lb. sample of the shelled peas as delivered is taken by the laboratory staff and is put through a small clipper cleaner to determine the amount of trash and waste. A smaller sample, usually 10 lb., is carefully graded for size in a small grader designed for that purpose, and the weights of the different sizes are recorded.

A composite sample is tested in the tenderometer for texture, which is a measure of tenderness or maturity. Samples of the different size grades are also tested by tenderometer. The tenderometer measures the pressure necessary to shear a sample of the peas in this specially designed instrument. Several canners and freezers stated that they desired the peas to test well below 90 on the tenderometer scale if the peas were to be considered of A, or Fancy, quality (Figure 54).

Records are kept of each grower's deliveries, and the price to him for each delivery will be governed largely by the "door tests" mentioned above.

Another test frequently made in the laboratory is the brine-flotation test. It is made somewhat as follows in one of the large canneries visited in 1955: Fifty peas are peeled by hand. The individual halves, 25 at a time, are placed carefully in a brine of 13° salometer in a beaker. Those that float are considered of A quality, and those that sink, within a certain time, B quality. Usually standard brines of several salometer degrees are made up in large bottles for ready use and for quick identification may be colored with dyes. In one laboratory the brines were 11, 12, 13, and 14° salometer. By using a range of brines the peas can be classified into several

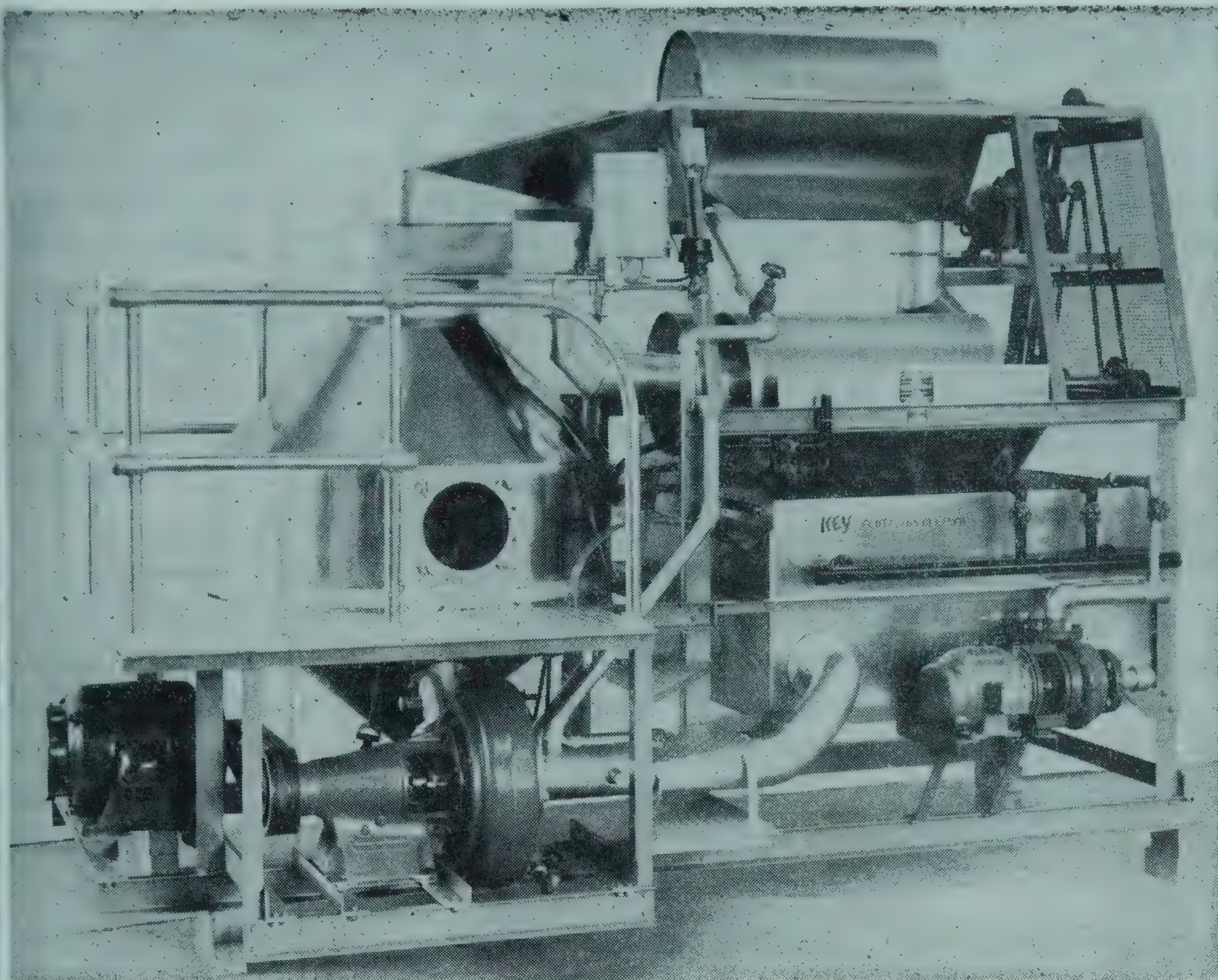


FIG. 56. Key froth flotation cleaner for peas and Lima beans. (*Key Equipment Co., Milton-Freewater, Ore.*)

grades. The test can be made after blanching and, if the peas are not too soft, after canning. See also Chapter 5 for the U.S.D.A. method of making the brine-flotation test.

The alcohol-insoluble matter was at one time used as a measure of starch content, and therefore of maturity, but in the Northwest, at least, is no longer used.

Occasionally it may be necessary to examine samples of the canned product for the presence of weevil or weevil damage, but present dusting practice in the fields eliminates most insects.

During the day many samples are taken after retorting and examined in the laboratory in respect to flavor, texture, color, freedom from defects, condition of brine, percentage of broken peas, and other points. If the plant is under Federal in-plant inspection, one or more representatives of the Federal service are present throughout the operating day, including the night shift. Frequent samples are taken by them at different stages in the preparation and processing departments as well as of the canned product. These are examined in accordance with the specifications of the service. On the basis of such examination the canned product is certified as to

Federal grade and the canner is permitted to print that information on the label and the fact that the plant is under Federal in-plant quality control.

The cannery's quality-control staff cuts a considerable number of samples of the previous day's pack each morning, and all key members of the cannery's staff examine and taste each sample. They then discuss the samples and decide whether any modifications should be made in operations in the plant.

See the U.S. Standards for Grades of Canned Peas published in May, 1955, "U.S. Grade A or U.S. Fancy," as given in Chapter 4.

The Blair and Ayres Process. Blair and Ayres of the American Can Company research staff published an interesting paper in 1943 on stabilizing and retention of chlorophyll in canned peas by alkalizing the peas before canning. The peas were first soaked at room temperature for 30 to 60 min. in 2 per cent sodium carbonate solution, then blanched in 0.037 per cent (0.005 M) calcium hydroxide solution, rinsed to remove the $Ca(OH)_2$, and canned in dilute brine containing 0.116 to 0.145 per cent (0.020 to 0.025 M) $Mg(OH)_2$ in suspension. The peas are given a short high process of 7 min. at 260°F., as color is much better retained thus than at the usual 240°F. for 40 min. The final pH after canning is about 7.6 compared with the 6.1 of normal canned peas.

Cooling. Cooling should be thorough and rapid following sterilization to avoid excessive softening and the formation of a cloudy brine through gelatinization of starch.

Cutout Standards. The normal net contents of a No. 2 can of peas is 20 oz., of which usually slightly more than 13 oz. consists of peas and the remainder of liquid. The U.S.D.A., Bureau of Chemistry, has ruled that a No. 2 can must contain 13.5 oz. drained weight of peas.

Spoilage. For discussion of spoilage see Chapter 11.

Causes for Substandard Peas. The canner desires to obtain the largest possible proportion of the best grades of peas, because therein lies the most profit. Bigelow and others have summarized the causes for substandard or low-grade canned peas as follows:

1. The use of a variety which does not ripen evenly, or of peas that have not been properly "rogued"; separated from off-type vines.
2. Lack of care as to time of harvesting, permitting too many peas to become overmature.
3. Allowing vines to stand too long after mowing, causing peas to ripen and harden.
4. Allowing peas to remain too long in boxes after being vined, caused by delay in hauling from viner or delay at factory.
5. Mixing of mature and immature peas in grading. During processing the mature peas swell and cause the pack to appear ungraded.

6. Permitting heating of the vines or hulled peas.

7. Excessive handling of unblanched peas, particularly in boxes. Smooth, perforated metal pails are preferable to boxes.

8. Underfilling or overfilling through lack of proper adjustment of the filling machine.

9. Improper cooling. Injures color and gives cloudy brine.

10. Use of hard water in blanching. Causes peas to be hard.

11. Too strong brine. This causes toughness.

12. Too long blanch.

13. Lack of judgment in varying the process to suit the character of the raw material.

14. Improper washing to remove adhering "dried-on" viner juice.

PIMIENTOS

Pimientos, large, red, smooth, sweet bell peppers, are canned extensively in the southern part of California and Georgia. They are successfully grown in other Southern states. They are also canned commercially in Spain, and the Spanish product competes with the product from California and Georgia.

Pimientos for canning purposes should be large, smooth-skinned (not wrinkled), deep red in color, and sweet in flavor.

The plants are grown in much the same manner as tomatoes, and the fields are picked frequently as the pimientos ripen. They are picked into baskets or lug boxes and delivered in sacks or crates in California. They are usually graded for size by rod-type grader. Number 1 size is more than 2 in. in diameter, No. 2 approximately 2 in. in diameter, and No. 3 less than 1¾ in. in diameter.

Peeling. Until recently the most satisfactory process of peeling consisted in roasting the pimientos until the skin could be easily slipped from the flesh. It is accomplished by passing the pimientos through a slowly rotating iron cylinder heated by gas flames, or by chain conveyer through a gas-flame-filled firebrick furnace. The rate of rotation of the cylinder is approximately 12 r.p.m., and the pimientos are heated for about 1 min. They then go through a spray washer, which removes most of the peel, and from there to the peeling tables, where the remaining skins are slipped from them by hand. The cores and stems are removed at the same time by a knife similar in construction to a peach-pitting spoon. The roasting not only removes the peels but also softens the flesh of the pimientos so that they may be flattened and packed tightly into cans. Bitting states that in Georgia the pimientos are first cored by a rapidly revolving cutter head. They are then peeled by roasting and spray washing.

In another peeling process the pimientos are heated in a vat of cottonseed

oil at a temperature of about 400°F. for about 3 or 4 min., which accomplishes practically the same result as the roasting process, although it is claimed that roasting imparts a desirable flavor that cannot be obtained by the oil-peeling process. The latest method of peeling pimientos is by heating at 45 to 55 lb. steam pressure for a short period in a Pfaudler or Food Machinery Corporation steam peeler and releasing the steam pressure suddenly. The loosened skins are then easily removed in a rotary screen washer.

In one California cannery the pimientos are first treated in boiling 10 per cent NaOH solution to loosen the skins. They are peeled by treatment at about 300°F. in an FMC continuous-steam-pressure peeler followed by spray washing to remove the disintegrated peels. They are next placed on traveling metal fingers with the stem end of each pimiento up. A coring knife similar to a cork borer descends and cuts out a cylindrical core which includes the seeds. The cored pimientos are vigorously spray-washed. They are then inspected, sorted, and canned.

Pimientos may be peeled with boiling lye, but lye peeling is not considered so satisfactory as other methods.

Canning and Sterilizing. The perfect specimens are flattened and packed carefully by hand into small cans or jars, and usually no liquor is added. In this respect pimientos resemble solid-pack tomatoes. In some canneries a small amount of water or dilute brine is added. Because of the solid consistency of the pack, it is necessary to exhaust the cans very thoroughly, preferably for 12 to 15 min. at 200 to 212°F. Small cans are processed in boiling water in an agitating cooker for 30 min., or in a stationary retort for a shorter period. Acidification may be desirable in some cases and is recommended by the National Canners Association. That agency should be consulted for advice.

RHUBARB
(Rheum rhaponticum)

Rhubarb more nearly resembles a fruit than a vegetable in composition. On account of its high acidity it attacks tin plate vigorously, and perforation of cans is common.

The rhubarb is washed and cut in short lengths. It is either packed at once into cans with water or is cooked a short time in a jelly kettle and packed hot into cans, the latter method being preferable because it gives a better-filled can.

The process is about 13 min. at 212°F. for the product canned raw; if sealed at 180°F. or above, the precooked rhubarb needs no further sterilization.

PUMPKIN AND SQUASH

Canned pumpkin has made pumpkin pie available at all seasons of the year, and pumpkin canning has become an important industry.

Pumpkin for canning should be of the hard, sweet varieties, evenly ripened. The flesh should be golden yellow and of good texture, not watery. The Golden Delicious squash is popular for canning. A mixture of squash and pie pumpkin is also satisfactory. The Connecticut field pumpkin is often used with a good variety of squash.

Pumpkin is canned late in the fall after the season for tomatoes has closed.

After the pumpkins and squash are washed and stemmed, they are cut in pieces by large knives or hatchets or by special roller disks, and the pieces are washed in a revolving circular-screen ("squirrel-cage") washer to remove seeds and fiber, or this material is removed by a revolving, blunt, broad cone against which the halved pumpkin is held by hand.

The pieces are then steamed in retorts at 240°F. for 20 min. until the pumpkin is well softened; or they may be steamed at atmospheric pressure in a continuous steam cooker designed for the purpose.

The pulp is separated from the skin and tough fiber by a heavy tomato pulper, and the pulp so obtained is usually passed through a finisher and then evaporated in open kettles to a heavy density and canned hot as a solid pack. Enamel-lined cans should be used to prevent darkening of the product.

No exhaust is necessary if canned hot. The process is usually conducted at 250°F. for 75 to 90 min. for No. 2½ cans, heat penetration being extremely slow because of the heavy consistency of the pumpkin. Number 10 cans require 165 min. at 250°F. In both cases an initial temperature of 180°F. is assumed. Those who contemplate the canning of pumpkin should consult a canning research laboratory.

A good can of pumpkin should be smooth, evenly screened, free from fiber, and uniformly colored. When opened, the can should be filled to within ½ in. of the top.

SPINACH
(Spinacea oleracea)

The commercial canning of spinach has become an important industry owing to the belief that it is high in vitamins and valuable mineral food elements and on that account a desirable food for children.

Culture and Harvesting. There are a number of strains of spinach. In California the Prickly Seeded, Amsterdam Prickly Giant, and Prickly

Winter varieties are more popular than the Savoy because the leaves are thinner. The Savoy is more commonly used by market gardeners. The Viroflay variety is grown in southern California.

In California the seed is planted in rows about 15 to 20 in. apart in the fall, usually in November. Spinach is fairly resistant to the mild frosts occurring in that state and grows during the winter and early spring without irrigation, as the winter rains supply sufficient moisture.

When the spinach has attained proper size and maturity, i.e., when the blossom stalks have begun to form, the plants are cut by machine.

In California spinach is now cut by a mower blade and cutter bar about 2 in. above the ground. A revolving reel forces it onto a draper that elevates it in the same manner as cut wheat or barley into a truck traveling beside the harvester (Figure 113 in Chapter 25). It is delivered in bulk to the cannery. The harvesting season in California is usually in April. In the Eastern states, spinach is sown in the spring as soon as weather conditions permit and is harvested in May or June. Spinach requires cool weather and is not a satisfactory summer crop. The principal difficulty is control of aphids that often grow in great numbers on the leaves. If the aphid population is excessive, the canner will not receive the spinach. Dusting with Nicodust has given partial control. According to A. E. Michelbacher, dusting the plants with TEPP gives very good control. It should be applied only when the plants are dry. If the leaves are wet, it is hydrolyzed and loses its killing power.

Spinach should be canned at once, since if allowed to stand very long, it is apt to rise in temperature, wilt, and deteriorate in quality. If for any reason it cannot be canned within a few hours after cutting, it should be placed in a cool well-ventilated room, with crates stacked so as to permit free circulation of air.

The U.S.D.A. has established standards for U.S. No. 1, No. 2, No. 3, and Unclassified fresh spinach for canning, based upon freedom from or presence of yellow leaves, decay, grass, weeds, roots, insects (aphids and worms), mildew, seed stalks, coarse stalks, wood, soil, or other foreign material. Canners sort and grade samples from each load and pay the grower accordingly, deduction being made from the contract price for presence of an excessive amount of unfit material.

Trimming and Sorting. Formerly, spinach was cut with crowns attached, so that trimming was necessary. As it is now cut above ground, trimming is omitted. A preliminary sorting is given on a broad belt as the spinach travels to the washer. It is again sorted after washing, to remove weeds, yellow leaves, and other unfit material. It is sorted again after blanching.

Washing. Because spinach leaves grow on or near the surface of the soil and are subject to heavy rains, they are apt to carry considerable soil. Aphids and small worms are sometimes present in considerable numbers.

Hence spinach leaves must be very thoroughly washed. Usually they are first carried through a long tank of water, where they are subjected to agitation and sprays. They then pass through several rotary-drum spray washers where they are subjected to heavy sprays of water under 60 to 200 lb. pressure per square inch. These cut most of the soil and many of the insects from the leaves.

The washed spinach should be sorted on a slowly moving belt to remove any defective leaves, weeds, and trash that may have escaped in preliminary sorting.

Blanching. The blanching of spinach has undergone considerable change since the preparation of the first edition of this book, in 1920 to 1923. At that time the following statement was made: "The blancher consists of a rotating screen cylinder which carries the spinach through hot water, the temperature of which is varied according to the tenderness of the product. For example, a temperature of 185°F. may be used for small tender leaves, 200°F. for medium, and 212°F. for tough leaves."

In September, 1928, a patent was issued on the blanching of vegetables to W. E. Thomas of the Thomas-Body Canning Company of Oakland, California. In the patent it is stated, "The maximum allowable temperature for the purpose is approximately 160°F." Oddly enough, the color of spinach so blanched is, after canning, more nearly like that of cooked fresh spinach than is that blanched at near the boiling point. The latter is gray to gray-green in color. There is difference of opinion concerning the cause of better green color retention in canned spinach blanched at about 160 to 170°F. Most spinach canned in California is blanched at about 170°F. for about 6 min. The inventor states in his patent application:

> It appears that the changes effected in the chloroplasts by the uniform and relatively slow heating thereof at the temperature specified are such as to render the chlorophyll thereafter less susceptible to the influence of heat for transforming it into phaeophytin. That such is indeed the case is further indicated by the fact that, after a period of not less than four minutes of the treatment at the fixing temperature, the temperature may then be raised without effecting a change in color of the vegetable.

The patent is held by a California canning company, but it has now expired. The California Packing Corporation holds a patent by Lesley and Shumate on the blanching of spinach. For further discussion of blanching spinach see Chapter 3.

The hot blanched spinach is again sorted on a moving rubber belt before going by conveyer to the canning tables.

Canning. The hot spinach is usually packed into cans by weight by women whose hands are protected by rubber gloves. Formerly the leaves were rammed tightly into the cans, but because heat penetration was

seriously retarded thereby, the California State Board of Health has established maximum cutout weights based on a moderately filled can. Filling by machine is also in use; it is a logical development, as the cans may then be filled very hot.

The maximum drained weights set by the California State Board of Health are as follows: for No. 1 Tall cans, 8.0 oz.; for No. 2 cans, 14.5 oz.; for No. 2½ cans, 21 oz.; and for No. 10 cans, 70.0 oz.

Brining. In California the dilute brine is added hot by a nozzle inserted into the contents of the can; or more commonly, water is added and a measured amount of granular salt or a salt pellet is added by machine after exhausting. Formerly a conical hole was made in the center of the can of spinach by plunging a conical wooden peg into the mass, and brine was filled into this hole, with or without previously injecting live steam into the mass.

Exhausting and Sealing. Number 10 cans require 10 to 14 min. exhausting. If they are sealed at too high a temperature, excessive paneling (partial collapse) will result after canning and cooling. Number 10 cans are usually sealed at about 150°F., and smaller cans at a somewhat higher temperature.

The exhausted cans are sealed in the usual manner. However, vacuum sealing is also common practice. In this case the cans are sealed directly after brining and without exhausting by heat.

Preheating. In most California canneries the sealed cans are passed through boiling water and steam in an agitating cooker to preheat the contents to about 180°F. and to break up matted masses of leaves.

Processing. Formerly the California State Board of Health required that canned spinach have an initial temperature before processing of at least 180°F., or that the process time be correspondingly lengthened if the initial temperature was below 180°F. At present, however, it is required only that the initial temperature be at least 140°F. The specified processing temperature is 252°F. One large cannery uses the following cooks: 47 min. at 253°F. for No. 2 cans and 52 min. for No. 2½ cans in still retorts; and

TABLE 24. PROCESSING TIMES FOR SPINACH AT 252°F. AND AN INITIAL TEMPERATURE OF AT LEAST 140°F.

Can size	*Time at 252°F., min.*
8 oz. Short	40
No. 1 Picnic	40
No. 1 Tall	50
No. 303	55
No. 2	60
No. 2½	70
No. 10	80

46 min. at 261°F. in a continuous retort for No. 2 cans, followed by 21 min. cooling under pressure. Since blanched spinach tends to stratify horizontally in No. 10 cans, it is recommended by the National Canners Association that these cans be processed in a horizontal position.

The process times recommended by the National Canners Association are given in Table 24.

Laboratory Control. Many samples of the fresh spinach are examined for aphid count. Samples of the canned are examined for aphids, worms, sand content, weeds, off-color leaves, etc. Definite maximum tolerances are enforced by food officials.

SWEET POTATOES
(Ipomoea batatas)

The potatoes are canned during October, November, December, and January, when the canning plants are not in use for other vegetables, and most of the canning is done in the Southern states.

Varieties. Two types are used for canning, viz., the yellow or Jersey type, grown in Delaware, New Jersey, Maryland, and Virginia, and the white type, grown farther south. Because of its yellow color the Jersey is preferred for canning. The Jersey is not so sweet as the white varieties but it is of good flavor and cooking quality.

Steaming. The potatoes are washed and placed in crates in a retort at 240°F. for 9 to 12 min. to soften and loosen the skins. A quick, high heating is better for the purpose than a longer cook at a lower temperature.

Peeling. The steamed potatoes are taken at once to the peeling tables, where workers with heavy canvas gloves slip the skins from the potatoes. If properly steamed, the skins slip from the potatoes readily. The potatoes do not peel satisfactorily if they have been allowed to stand so long after digging that they have become shriveled.

Sweet potatoes are also peeled by use of the lye peach-peeling machines described elsewhere, but a stronger lye solution and longer lye treatment are required than for peaches. Revolving brushes are used in addition to water sprays to remove the lye-softened skins. Hand trimming is usually necessary with lye-peeled potatoes.

Abrading machines, such as those used for carrots, can be used for sweet potatoes, although the waste in peeling is high and considerable hand trimming is required. It is likely that they can be peeled by the Pfaudler and Food Machinery Corp. steam-pressure peelers, in which the product is heated at very high temperature under steam pressure for about 45 sec.; whereupon the pressure is released instantaneously to "explode" the skins, followed by spray washing.

Lye-peeled potatoes or those peeled by machines are steamed to soften them before packing.

Packing and Sterilizing. The hot peeled potatoes are tightly packed at once into sanitary cans with the addition usually of a small amount of water. The cans are heaped full, and the potatoes are pressed in tight.

A long exhaust is desirable, because the solid-packed potatoes conduct heat very slowly. Bitting recommends 18 min. at 185 to 200°F. The National Canners Association recommends the following 240°F. processes if the initial temperature is 150°F.: No. 1 Picnic size can, 65 min.; No. 2 can, 95 min.; and No. 2½ can, 110 min. If the initial temperature is 180°F., the times at 240°F. are 60, 85, and 95 min., respectively. For vacuum sealing at 80°F. the process is 110 min. for No. 2 cans and 130 min. for No. 2½ cans.

Darkening and Springers. Overfilled cans become springers and, although wholesome, are not purchased because of their bulged appearance.

Potatoes in slack-filled or insufficiently exhausted cans may blacken, a condition caused by solution of iron, its oxidation to the ferric condition, and its combination with the tannin of the potato.

White Potatoes. Small, new white potatoes are washed, abrasion-peeled, trimmed, sorted, and canned in dilute brine. The National Canners Association recommended processes are 30 min. at 240°F. for No. 2 cans and 35 min. for No. 2½; 20 and 25 min., respectively, at 250°F. The initial temperature is 140°F. or above.

TOMATOES
(Lycopersicum esculentum)

According to Bitting, the first recorded canning of tomatoes was done by Harrison W. Christy in 1847 at Jamesburg, New Jersey. Tomatoes are now used in enormous quantities in the fresh state, as canned tomatoes, and in the form of juice, purée, paste, and various relishes, such as catsup, chili sauce, etc.

Importance of the Industry. Tomatoes at one time headed the list of canned fruits and vegetables in quantity, although in recent years they have usually been exceeded by corn or peas.

Worsham has studied the data for production and consumption of tomatoes and has arrived at the conclusion that the consumption of canned tomatoes other than juice is decreasing. He attributes this decrease to the importation of tomatoes during the winter and spring from Mexico and the Southern United States and to the increase of home gardening with consequent increase in the home canning of tomatoes. It is possible also that the greatly increased use of canned citrus-fruit juices has lessened the demand for canned tomatoes by providing other foods of acid taste

and low calorific value. Another factor is the tremendous increase in consumption of tomato juice.

The total United States pack in 1954 was 20,964,000 cases and in 1956 was 28,678,000 cases, according to *Western Canner and Packer*. The California pack in 1956 was 11,592,000 cases.

Varieties of Tomatoes for Canning. Tomatoes for canning should be moderately large, smooth, so that peeling can be easily accomplished, evenly ripened to the stems, of a clear red color, and possessing a large proportion of solid meat of good flavor. Those of irregular shape and wrinkled skins are difficult to peel, and the loss in preparation is excessive. Some varieties possess large seed cavities and on this account soften badly in the can, giving an unattractive appearance and a slack-filled can. Soft, watery varieties are objectionable for similar reasons. Yellow and purple tomatoes are not desirable; a deep, uniform red color is the ideal. Lack of uniformity in ripening excludes some varieties for canning.

Not only must the tomato possess desirable canning qualities; it must also yield well to be grown profitably. Early ripening, therefore, is desirable, since yield is largely influenced by the length of the picking season.

Seedsmen and others have developed a number of excellent strains of tomatoes for canning purposes. Of these, the Stone is perhaps the best known and most widely grown. It is a medium-large, smooth-skinned, bright red tomato with a large proportion of solid meat. It is a regular bearer but ripens over a comparatively short season.

The Pearson is popular in California for commercial canning. At one time the Santa Clara Canner was the most important canning variety in this state, but now is seldom used. It is a variety of large size, somewhat irregular shape, and of good color and flavor. In southern California the Norton, said to be a Stone selection, is grown because it is fusarium wilt–resistant. The Pearson is a heavy bearer of medium-size fruit and is now the most important canning variety in northern and central California. It need not be picked as often as most other varieties, a great advantage from the grower's standpoint. The Moran is another heavy-bearing variety grown for canning in this state. The San Marzano, a small pear-shaped variety from Italy, is used extensively for paste production. It is also used for canning whole after peeling. Much research on new varieties is being done by G. C. Hanna of the University of California.

The Matchless is said to be grown extensively in Delaware and Maryland. It is oblate in form in vertical section and circular in horizontal section. It is of large size and relatively free from corrugations, and the flesh is firm and of reddish-pink color. The pulp around the seed cavity is yellowish red. It ripens rather late and is claimed to be a more irregular bearer than the Stone. Several of the large producers of tomato products have developed varieties of their own.

The Paragon is a large, flattened, solid, bright red tomato of good canning quality and early ripening. It has a tendency to develop prominent ribs.

The Landreth is said to be an excellent canning variety. Other canning varieties reported as being grown commercially outside California are the Coreless, Perfection, Greater Baltimore, Favorite, Red Rock, and Success. The nearest state agricultural experiment station should be consulted for varieties recommended for canning in the state concerned.

Propagation. Canners have found by experience that it is desirable for the canners themselves to propagate the young plants in hotbeds and cold frames in order that the proper varieties shall be grown. When the purchase or propagation of young plants is left to the choice of the growers, the cannery will usually receive several varieties, of varying canning quality. In California the young plants are set out about May 1 in a deep, well-prepared seedbed, each plant receiving about a quart of water. Many are grown under irrigation, but some receive no irrigation or rain after planting. Clean cultivation is practiced in nonirrigated fields to keep moisture-wasting weeds in check.

Picking and Transportation. The picking season varies with the locality. In California, picking for canning purposes usually begins about Aug. 5 to 10 and continues until about Nov. 15. In Maryland the season is approximately from Aug. 20 to Oct. 20; in Indiana, Aug. 1 to Nov. 1 except in years of early frost; and in some of the Southern states from about July 15 to about Oct. 15. As previously mentioned, the Pearson bears heavily, yields of 20 tons or more per acre being common.

Tomatoes for canning must be prime ripe, without green areas around the stem end, and not overripe. In order to secure tomatoes in this condition the fruit must be gathered frequently, otherwise a great deal of it will become overripe.

Shallow boxes are to be preferred to deep baskets or deep boxes. The tomatoes in the bottom of a deep container are subjected to considerable pressure and may become crushed or cracked during transit. Boxes should be provided with cleats across the ends, to prevent crushing when the boxes are piled one above the other and to provide ventilation between the boxes. Pickers use baskets or buckets and place the tomatoes in 50-lb. lug boxes. In other states baskets are often used as final containers.

Tomatoes should not be allowed to stand in the fields in the sun after picking, because this will cause overripening and development of microorganisms. Instead, they should be transported to the cannery as promptly as possible and without undue bruising or crushing in transit.

Vinegar Flies. The vinegar fly, *Drosophila melanogaster*, is an exceedingly troublesome and costly pest in the production of tomatoes for canning and for tomato products. The insect's eggs are laid on the tomatoes in great numbers, and many are apt to be carried through manufacturing operations

into juice, paste, catsup, and other products. As tomatoes are peeled for canning, the eggs are much less apt to be found in this product.

Observations made by Michelbacher of the University of California and research members of the National Canners Association's staff indicate that most of the eggs are laid on the tomatoes after picking.

Dusting of the vines in the field by airplane with a suitable insecticide gave partial control. Forcing a fog of pyrethrum solution into truckloads or stacks of lug boxes of tomatoes was fairly effective. Prompt canning after picking is a useful means of minimizing infestation (see references at end of chapter, and Chapter 16).

Sampling at Factory. At the factory, immediately on delivery, a representative sample should be taken by the canner, and the proportions of prime, rotten, wormy, and green fruit determined. This can be done by dumping one or two boxes, taken at random, into a tank of water and sorting the sample carefully. The grower can then be paid for the fruit which is suitable for canning purposes and "docked" for rotten, wormy, and green fruit. By no other means is it possible to maintain a delivery of desirable fruit and reduce to a minimum the delivery of unfit material. Particularly is this true near the end of the season, when early-fall rains have damaged a large proportion of the crop. The U.S.D.A. has established specifications for U.S. No. 1, U.S. No. 2, and Cull grades upon which canners may purchase tomatoes. This has been done to a limited extent but is not general practice in California. If the tomatoes are to be used for products such as catsup, they are carefully inspected by the canner and usually, in California, by the State Board of Health inspectors, for rot and insects.

Storage at Cannery. Tomatoes deteriorate rapidly after delivery and should be canned as promptly as possible; if there is delay in canning, they should be stored in the shade. See earlier section on vinegar flies.

Washing Empty Boxes. Under the best conditions picking boxes become contaminated with mold, yeast, and bacteria which develop in tomato juice or pieces of pulp on the bottoms and sides of the boxes. Therefore boxes should be thoroughly washed and steamed at the cannery before return to the grower.

Washing. Although the washing of tomatoes is not so important in canning as in the manufacture of tomato pulp, washing the fruit before scalding is often desirable. This is especially true after rains and where the fruit may have been grown in close proximity to wet clay soil.

Washers. An efficient washer for tomatoes consists of an inclined, perforated metal drum fitted on the inside with longitudinal corrugations. The tomatoes rub against each other as they traverse the cylinder and are subjected to heavy sprays of water. The rubbing softens the dirt, and the sprays remove it. While very effective, this washer is apt to be too severe

on tomatoes for canning; the roller conveyer with powerful sprays is more suitable (Figure 57).

Another common type is the apron washer. The tomatoes are carried on a door-matting conveying belt, or (in California at least) on a roller conveyer, beneath sprays of water. The rollers turn the tomatoes over and over, so that sorting and trimming are greatly facilitated. Sprays may also be played against the tomatoes from below the belt with good effect. This washer is less liable to break or bruise tomatoes for canning. Some canners now wash tomatoes by heavy jets of water under very heavy pressure, as high as 400 lb. per sq. in., as they are carried through a shallow

FIG. 57. Tomato washer, roller sorting apron, and scalder. (*Food Machinery Corp.*)

compartment by conveyer. (Note the high-pressure washing section at the left of Figure 57; see also Figure 18.) Simply allowing the tomatoes to pass through a tank of water adjacent to the scalding machine usually does not remove the dirt effectively.

Testing. The effectiveness of the washing process can be determined by allowing some of the tomatoes to dry in the air after washing. If they have not been thoroughly washed, a film of dirt will be evident on the dried fruit. The water used in washing must be renewed frequently; otherwise it may add more dirt to the tomatoes than it removes.

Sorting and Trimming. In the majority of tomato-canning plants, the peelers did most of the sorting until recently. However, sorting can be more efficiently and satisfactorily done by a few sorters than by a number of peelers. Peelers are apt to be more careless in the sorting of the tomatoes. If the washed tomatoes are very carefully sorted in such a manner that only the large perfect fruit goes to the scalder, the rotten fruit to the dump, and the small and misshapen fruit to the pulping line, sorting will be a very profitable investment. Only the best tomatoes should be used for canning. Small, badly wrinkled, unevenly ripened, and overripened fruits should be used only for pulping.

Tomatoes that carry a small amount of rot or green areas may often be trimmed and used for canning as standard grade.

In sorting and trimming, the tomatoes were formerly carried on a broad belt or woven-metal conveyer before the sorters. For effective sorting, the belt should move at a rate not to exceed 25 ft. per min. According to B. J. Howard, it should be equipped with turning devices at regular intervals, as experience has shown that the sorters otherwise allow many of the tomatoes to pass without turning, thus permitting unfit fruit to pass to the peeling tables. Roller conveyers which turn the tomatoes as they travel are now generally used as sorting "belts" before the tomatoes go to the scalder and peelers (Figure 57).

Coring before Scalding. It is customary in many canneries to core the tomatoes before scalding and peeling.

The coring is done by a small machine made by Magnuson Engineers of San Jose, California, and known as a Hydrout. It is a water-powered device in which is mounted a small turbine wheel spun by a jet of water; a special blade mounted on the turbine wheel spins and neatly cuts out the core of the tomato. The knife and turbine are enclosed in a rubber cage. The operator merely presses the stem end of the tomato into a hole in the top of the housing, and the spinning knife cores it. The machine uses about 1 gal. of water per minute. The water washes away the cores and other debris. The Hydrout greatly increases the output per worker compared to that of coring by hand. It is also said to increase yield by reducing waste in coring.

Scalding. Tomatoes are scalded sufficiently to loosen the skin but not so long that the pulp and flesh become softened or the tomatoes thoroughly heated. The scalding is accomplished by conveying the tomatoes through boiling water or live steam. Very often the same conveyer that carries the tomatoes before the sorters carries them through the steam scalder, which in this instance is merely an enclosed sheet-metal box filled with sprays of live steam.

The tomatoes are exposed to the live steam or boiling water from ¼ to 1 min., depending upon their condition. As they emerge from the scalder they are subjected to sprays of cold water or are immersed in cold water to check further cooking and to crack the skins (Figure 57). If the tomatoes have been cored by the Hydrout, it is recommended that they be scalded in steam.

Hand Peeling. The scalded tomatoes are delivered by conveyer or in dishpans or buckets carried on belts to the peeling tables, where they are peeled by hand. Prompt peeling is essential in order to avoid incipient spoilage.

The tomato is peeled by first pulling the skin back from the blossom end with the blade of a short coring and peeling knife. The operation is completed by removing the core with the point of the knife, which is directed toward the center of the tomato to avoid opening the seed cavity.

A knife commonly used for this operation is spoon-shaped. Green and otherwise undesirable spots are removed by the peelers.

The peeled tomatoes are usually conveyed by a belt to the canning department.

The sound cores and peels are usually placed in buckets or on a belt for the production of purée. Unfit trimmings and rotten pieces are discarded. In California only about 25 per cent of the tomato crop is used for canning, according to Magnuson Engineers, the remainder being used for tomato products.

Pans, buckets, conveyers, and all machinery used in the handling and treating of tomatoes in the cannery should be washed frequently. Floors require special attention in this regard. A clean plant encourages cleanliness and care on the part of the employees and will improve the quality of the pack on this account.

The loss in peeling, according to Howard, ranges from 20 to 50 per cent, depending on the condition of the tomatoes as well as on the care and skill of the peeling crew. Experienced, careful peelers may waste only 20 to 25 per cent, whereas careless peelers may waste much more.

Fancy Quality. The whole, evenly colored, large tomatoes are carefully packed by hand into cans as Fancy, or A grade. Formerly the can was filled completely with the whole, peeled tomatoes and no additional liquid was added; but at present the cans are filled reasonably full and a light purée of high quality or juice is added to fill. The former solid-pack procedure often crushed the tomatoes in the top of the can.

Standard Pack. Standard-pack tomatoes consist of the small tomatoes, those of imperfect color, soft tomatoes, and trimmed tomatoes. Purée is added to fill, after sufficient Standard-grade tomatoes has been added to fill the can about two-thirds full. The standard tomatoes are just as nutritious and wholesome as the solid pack and are cheaper. Therefore they have a legitimate place, if carefully prepared and not mixed with too much purée.

Stewed Tomatoes. This product is now of commercial importance. Production procedure varies, but the following is fairly typical. The can is filled about three fourths full with peeled, cored, coarsely chopped tomatoes. There is then added a pellet containing salt, sugar, calcium chloride, and small amounts of certain spices, usually thyme, marjoram, and black pepper, plus a small amount of garlic. The pellets are furnished by a spice and seasoning supply house. There is also added dehydrated chopped celery, green bell pepper, and onion flakes. These dehydrated products are usually refreshed in water before addition.

The can is then filled with tomato juice, exhausted, double seamed, and processed in much the same manner as unflavored tomatoes. Steamflow closure may replace exhausting by heat.

Addition of Water. The addition of water to tomatoes is never necessary or desirable and constitutes an adulteration. Bitting has studied the effect on the composition of the canned product of the addition of various amounts of water at the time of canning.

Addition of Calcium Chloride. As a result of the research of Z. I. Kertesz of the New York Agricultural Experiment Station, it is now standard practice in many canneries to add $CaCl_2$ to canned tomatoes. A small measured amount is added automatically to each can as it passes beneath a dispenser. The calcium ion makes the texture of the tomatoes firmer. The amount used is so small that it does not affect the flavor of the tomatoes and is harmless to the consumer.

Exhausting. Tomatoes should be thoroughly exhausted at a moderate temperature, because solid-packed tomatoes heat very slowly. The center of the can should reach at least 130°F., if possible 160°F., and the length of the exhaust should be adjusted to accomplish this end. Too short an exhaust may result in springers or flippers through overfilling. Exhausting in steam is frequently omitted, the cans being prevacuumized and sealed under vacuum or in an atmosphere of steam (steam flow or steam vac).

Processing. The agitating continuous cooker for tomatoes, operating at 212°F., has largely superseded the retort and the open still cooker. Most canners of tomatoes are also canners of fruits and find it convenient and economical to utilize as far as possible the same equipment for both products. Considerable use is also made of continuous pressure cookers.

In an open nonagitating cooker, tomatoes are sterilized for 40 to 55 min. at 212°F. in Nos. 2½ and 3 cans. The length of time varies according to the consistency of the pack. Fancy grade whole tomatoes conduct heat more slowly than standard-pack goods and hence may require a longer processing. In the agitating continuous sterilizer the time has been 25 to 30 min. However, considerable spoilage may occur unless the centers of the contents of the cans attain 190°F. or higher. A large canning-machinery company recommends 200°F. minimum temperature at can center. For a No. 2½ can this will require about 30 min. in an agitating cooker. Temperatures are taken regularly during the day by plunging an armored, sharp-pointed thermometer into the centers of several cans taken directly from the outlet of the cooker. During the 1937 season in California the process of 25 min. at 212°F. failed to prevent spoilage in all cases, owing to the high pH of the tomatoes and the presence of a heat-resistant bacillus. One California cannery processes No. 2½ cans of tomatoes for 18 min. in an FMC continuous agitating retort at a temperature considerably above 212°F.

Tomatoes should be cooled completely and quickly after sterilizing, in order to avoid "stack burning," i.e., browning of the color and loss in flavor.

Cutout Weights. The total net contents of a No. 2½ can should weigh at least 28 oz., of a No. 3 can 33 oz., and of a No. 10 can at least 103 oz., although no minimum standards for net drained weights have been established by the government. It has been ruled, however, that head space must not exceed 10 per cent of the total inside height of the can. Tomatoes vary greatly in consistency and in the weight of the drained material on the cutout test, according to variety, grade, season, location, and the temperature and time of sterilization.

Sanitation. Buckets and pans should be washed each time they are used, and floors should be washed at least twice daily. Floors and belts should be washed with water containing a moderate concentration of free chlorine. Machinery should be washed frequently, which in some cases means partial dismantling and hand scrubbing of working parts.

If tomatoes are to arrive at the plant in sound condition, lug boxes must be frequently washed.

In short, cleanliness and orderliness in and about a cannery are essential to satisfactory operation.

U.S. Grades. The U.S.D.A., Agricultural Marketing Administration, specifications for grades of canned tomatoes are given in Chapter 4. See that chapter also for discussion of quality control.

SIEVED VEGETABLE BABY FOODS

As was mentioned in Chapter 8, Canning of Fruit, sieved fruits and vegetables in 202 × 214 size cans and 4.85-oz. jars for use as baby foods have become very important commercial packs. See that section for a general discussion of these products.

Sieved Carrots. The carrots are usually peeled by preheating at 45 to 55 lb. steam pressure for about a minute, followed by instantaneous releasing of the pressure and washing off of the loosened skins; or they may be lye-peeled as described in Chapter 19, Dehydration of Vegetables. They are then trimmed, ground, precooked in steam, pulped, finished, preheated, canned or glassed, and processed at 240°F.—usually in a discontinuous retort, but a continuous retort can be used. The process varies somewhat according to locality and plant conditions. A typical process for the 202 × 214 cans is 40 min. at 240°F. in a continuous cooker if the initial temperature is 140°F.; or 35 min. if the initial temperature is 180°F. However, an article in *The Canner* of July 20, 1946, states that sieved vegetables are processed at 240°F. for 60 min. in a still retort at a large sieved-foods cannery in New York State. In any event, those undertaking to pack a nonacid food for the first time should secure advice as to process time and temperature from a laboratory serving the canning industry. For larger

cans, such as No. 2, accurate heat-penetration data will be needed plus the advice of an experienced canned-foods bacteriologist.

In some plants the precooking is done in a continuous screw, or draper, steamer; in some the vegetables are precooked in stainless-steel kettles.

Beets. Small globe-shaped beets of deep-red color are preferred. As outlined in an article (*Western Canner and Packer*, March, 1946), the general procedure in a California plant is about as follows:

The beets are carried by a roller-type sorting belt at which women trim off the tops and roots and remove unfit beets. The beets are next washed in a revolving reel spray washer, heated at 45 to 55 lb. in a steam peeler, and the skins removed in a reel washer. The beets are then trimmed at a long sorting belt by women, washed again in a reel washer, cooked in a screw-type preheater, ground in a food grinder, collected in a stainless-steel holding tank, pulped, finished, heated, canned or glass-packed, processed, and cooled. The process is usually as given for carrots.

Spinach. The leaves from the field are carefully inspected and sorted after a preliminary examination for degree of aphid infestation. The leaves are then washed in a soaker tank with powerful jets of water and are further washed in a rotary washer. A third washing may be given, the purpose being to remove aphids and sand.

The thoroughly washed spinach is again sorted, steam-blanched, pulped, finished, collected in a stainless-steel tank, preheated, canned or glass-packed, and processed in a continuous pressure cooker 40 min. at 250°F. if the initial temperature is 140°F.; 35 min. if the initial temperature is 180°F.

Peas. Harvesting, shelling, clipper cleaning, washing, and sorting are as for canned peas, except that great care is taken in washing and an attempt is made to get the peas to the cannery very promptly after vining.

The peas are precooked in a continuous screw steam cooker or in kettles, pulped, sieved, mixed in a receiving tank and heated, canned or glass-packed hot, sealed, and processed. One authority, a retort-machinery manufacturer, gives the desired process as 50 min. at 240°F. for the baby-food size of can; 35 min. at 250°F. The processes in a continuous pressure cooker are briefer; one canner processes 18 min. at 246°F. in such a retort.

The consistency is carefully controlled, blending and adjusting being made to compensate for variations in consistency caused by variation in starch content.

Mixed Vegetables and Meats. Typical mixtures are beef, carrots, and potatoes, or lamb and mixed vegetables such as peas, carrots, and potatoes. Soups are quite thick in consistency and are made up of meat plus mixed vegetables. The meat is ground, thoroughly cooked under pressure, sieved, and blended with mixed sieved vegetables such as potatoes and carrots, or the ground meat and vegetables may be mixed. Rice or other thickener may

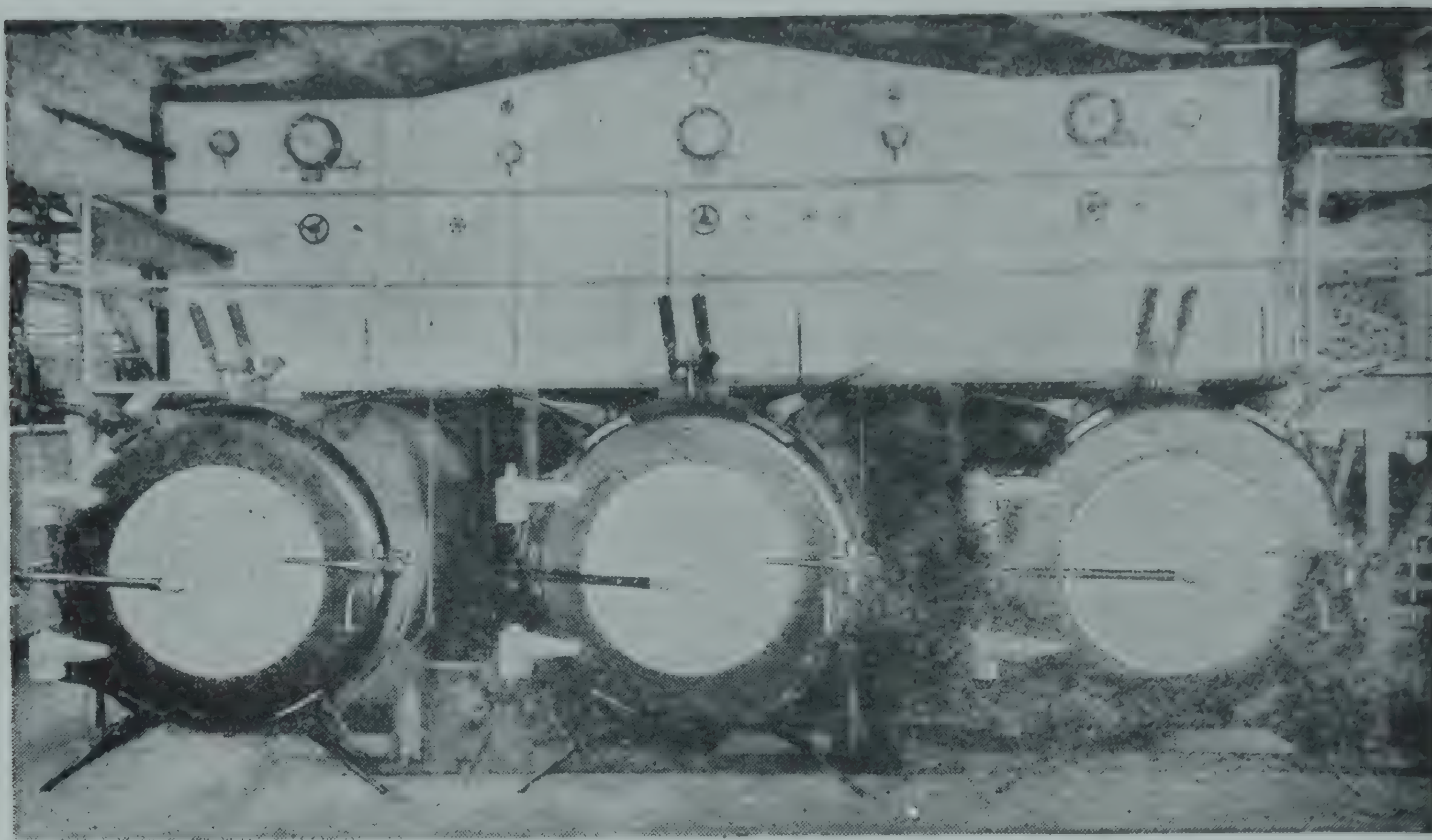


FIG. 58. Horizontal retorts for vegetables and olives. (*Foxboro Instrument Co., Foxboro, Mass.*)

be added. The mixture is sieved, preheated, canned, and processed. Usually the process is for 5 min. longer at 240°F. than for the plain vegetables; but on this point it is highly advisable to seek the advice of an experienced bacteriologist of some canning-industry laboratory. It is best to err on the side of safety in processing nonacid baby foods.

Miscellaneous Sieved Foods. Various sieved specialties are canned, such as rice and meat, various desserts, etc.

State and Federal Control. Baby-food canneries should be, and usually are, clean, sanitary, and neatly kept. They are subject to inspection by state and Federal food inspectors in respect to sanitary conditions, cleanliness, fitness of the raw material, presence in the foods of spray residues or of copper and other heavy metals, and the label information. In California all processes (sterilization times and temperatures) are also subject to State Board of Health approval and inspection.

Continuous Federal inspection and certification of quality is optional.

Consistency Control. Consistometers of various types are used in the canneries' laboratories to measure consistency of each day's output in order to ensure uniformity.

National Canners Association Processes. *In National Canners Association Bulletin* 26-L the following process times at 240°F. are given for sieved baby foods in small cans of 202 × 214 size; for an initial temperature of 140°F. or above: asparagus 40 min., green beans 40 min., Lima beans 50 min., beets 40 min., carrots 40 min., peas 50 min., spinach 45 min. For the so-called "junior" (chopped) foods and an initial temperature of 150°F. or

above and a retort temperature of 240°F., the times are green beans 55 min., beets 50 min., carrots 50 min., spinach 75 min. Can size for the junior (chopped) vegetables is 208 × 401.

In small jars of sieved baby foods and an initial temperature of 140°F. or above and a retort temperature of 240°F., the times specified are green beans 45 min., beets 45 min., carrots 50 min., peas 50 min., spinach 55 min. Size of jars is 200 × 309.

OTHER PRODUCTS

Hominy. Hominy is a food product first made by the Indians in North America by treating dry corn with wood ashes and water until the skins were loosened. These were removed by hand, and the corn washed thoroughly to remove hydroxide and carbonate dissolved from the wood ashes. The peeled corn was then cooked as a staple food product. The early white settlers adopted and improved upon the Indians' product and process.

The first step in canning at present is to treat white field corn of a variety with large flat kernels in boiling 2 per cent lye solution until the skins will slip easily, the time required usually being 25 to 40 min. The corn and solution must be stirred, but not too violently, during boiling in order to secure even action of the lye solution.

The lye is then drawn off and replaced with fresh water to remove adhering lye from the kernels. It is then run through a hominy huller which resembles a truncated tomato pulper with a coarse wire screen. This removes the hulls and most of the tips. The hulled corn is transferred to a tank where it is washed and then boiled in several changes of water to remove all traces of lye and to cause the corn to absorb water and become more or less plump. It may then be left in a tank overnight in cold water to absorb water before canning, or may be canned directly from the cooking or blanching tank. If canned without additional soaking less corn is filled into the cans in order to allow for increase in volume of the kernels during retorting and storage.

The hominy is sometimes bleached by treatment by boiling it in water to which has been added about 1½ oz. of sodium bisulfite for each bushel of hominy, a boiling period of about 15 min. being used. The bisulfite must be leached from the hominy pretty thoroughly before canning, as it may be broken down to sulfide in the can. Proper lye peeling, washing, and precooking are usually sufficient to prevent discoloration and thus make sulfite bleaching unnecessary.

The hominy is canned in C-enamel cans, a light brine added, and cans exhausted, sealed, and retorted. The National Canners Association recommends the following processes (initial temperature 140°F. or higher):

No. 2 cans	75 min. at 240°F.
No. $2\frac{1}{2}$ cans	90 min. at 240°F.
No. 10 cans	100 min. at 240°F.

Stainless steel should be used for tanks and other cooking equipment as steel or iron may cause discoloration. Overtreatment in lye solution or failure to thoroughly remove residual lye from the kernels by washing and cooking may cause dark spots or darkened kernels. Overnight soaking of the blanched hominy before canning may permit souring by bacterial action if cleanliness and sanitation are lax.

Pork and Beans. This is a product of major importance in the canning industry, although it is seldom packed by canners of fresh fruits and vegetables, and since this book is intended primarily for use by processors of fresh fruits and vegetables, canning of pork and beans will be discussed only briefly.

Small white beans of the types known as "navy beans" or "pea beans," the navy beans being about $1\frac{1}{2}$ times as large as the pea beans, are used. Both are of the familiar bean shape, not pea-shaped.

In California, at least, the beans, after harvesting, threshing, and machine cleaning by the grower, are now often sorted by an electric-eye sorting machine that removes all defective and off-colored beans and all stones. However, many beans are not sorted in this manner, and at the cannery it is usually advisable to carefully hand sort the beans from slowly moving short belts to remove defective beans of all sorts, stones, and any other foreign material and trash. Stones can also be removed by fluming the beans over riffles, which catch the stones and allow the beans to be carried over by the stream of water.

Next they are thoroughly washed to remove dust and fine trash. They are then soaked in water to plump them to more or less full size, the amount of water absorbed being about equal to the weight of the dry beans. Beans grown in the West, as in California, may require a short blanch in water before soaking, as they are usually dryer than those grown in the East and the skins more impervious to penetration of the cold water used in soaking. Soaking is usually overnight, or about 16 hr. Stainless steel or glass-lined steel tanks are preferable to wooden tanks because of the danger of build-up of bacteria in the pores of the wood. The water should be changed once every 4 to 6 hr. during soaking, preferably four to six times during the soaking period. Soft water is preferable to hard as the calcium or magnesium of the latter may cause hardening of the bean tissues.

The soaked beans should be plump, white with a tinge of yellow, semitranslucent, and free of any suspicion of sour odor or taste. The skin should be intact.

The next step is blanching. Bitting recommends a blanch of about 4 min., presumably at or near the boiling point of the water, but states that

blanching times up to 30 min. have been used commercially. An unduly long blanch removes much of the water-soluble food and dietary values from the beans. It should be long enough only to remove the peculiar raw-bean flavor and odor of soaked dry beans.

Only salt pork of good to excellent quality with strips of lean should be used. It is washed to remove salt crust, cut in strips, and the strips cut crosswise into rectangular pieces of more or less cube shape. Bitting states that the usual amount of pork per No. 2 can is $\frac{2}{3}$ oz., and for a No. $2\frac{1}{2}$ it is $\frac{7}{8}$ oz. More may be added, of course, as the consumer would greatly appreciate a more generous allowance of this meat in his pork and beans. The meat is placed first in the can, and soaked, blanched beans are added. The can is then filled with a sauce.

The sauce may be plain sauce or tomato sauce. Many formulas are in use, as each canner develops a formula or formulas to suit his distributors and customers. A basic formula for a plain sauce may be somewhat as follows: 100 lb. of water, salt 2 to $2\frac{1}{2}$ lb., sugar 6 to 9 lb., and spices to suit. The most common spices used for this purpose are cinnamon, mace, cloves, and allspice, added in the form of the oils or concentrated extracts, rather than as the dry spices. Garlic and onion may also be included. Some or most of the sugar may be replaced with high-quality molasses. Starch may also be added to improve the consistency of the canned product.

The tomato sauce is made in much the same manner as catsup except that the vinegar is often omitted and less sugar is used.

If the sauce is added hot, the cans may be sealed in an atmosphere of steam (steam flow or steam vac), or they may be well exhausted in steam and sealed hot in a plain double seamer.

The National Canners Association recommends the following cooks: in all cases the initial temperature is taken as 140°F.; No. 1 cans 70 min. at 240°F., 60 min. at 245°F., and 50 min. at 250°F.; No. 303 size cans 85 min. at 240°F., 75 min. at 245°F., and 65 min. at 250°F.; add 10 min. to these times for No. 2 cans. See *National Canners Association Bulletin* 26-L for processes for other sizes of cans and for other initial temperatures. As tomato sauce is rather easily damaged in flavor and color at high retort temperatures it is recommended that 240°F. be used for beans canned in tomato sauce.

Oven-baked or Steam-baked Beans. Baking implies that the beans have been treated to give an effect similar to that obtained by baking beans or pork and beans in an oven in the home. Commercially it can be done by heating the soaked, blanched beans in shallow pans in an oven, continuous or batch, or by heating in dry steam in shallow pans at 240°F. or higher until they are slightly browned and take on a baked flavor. The beans can also be baked in the cans before addition of sauce. In any event a sauce is added to the beans after canning, with or without added salt pork.

Canned Dry Lima Beans. Dry Lima beans are at present canned to a limited extent in much the same manner as navy or small white beans or with ham chunks in place of salt pork.

In experiments conducted at the University of California dry Lima beans of the so-called large Lima bean type were sorted, washed, and heated for about 10 min. in boiling water and then allowed to stand several hours to become plump. They were then canned experimentally with various meats and various sauces. Ham chunks, pieces of sausage or frankfurters, and pieces of corn beef cut in cubes all gave canned products of pleasing flavor and appearance, using a light tomato sauce or a dilute brine as filler.

A very satisfactory meatless product was canned in the following sauce:

Tomato sauce (usual type canned for household use)	3½ lb.
Water	3½ pt.
Chili powder, regular commercial	1 oz.
Gentry's barbecue powder (C. B. Gentry Co., Los Angeles)	1 oz.
Garlic powder, commercial	⅛ oz.
Cumin powder	⅛ oz.
Salt	1 oz.

The beans were first prepared as described above, canned, sauce added to fill, cans exhausted at 200°F. for 6 min., sealed hot, and retorted at 240°F. for 90 min. for No. 1 Tall cans. The product resembles Mexican-style beans in appearance and flavor. It is improved by the inclusion of diced beef or ham.

Retention of Nutrients in Canning of Vegetables. During the blanching of vegetables for canning or freezing some loss of the water-soluble vitamins and minerals is encountered. This subject has been covered in Chapter 3, Washing, Blanching, and Peeling Fruits and Vegetables. Cameron et al. have reported on retention of nutrients in canning.

During the retorting of canned nonacid vegetables the loss of thiamine, vitamin B_1, is appreciable. For example, several samples of spinach showed a retention of 77 per cent of their original thiamine content after blanching and only 23 per cent after retorting. Peas showed a retention of 73 to 92 per cent in blanching and only 39 to 64 per cent after retorting. The foregoing observations are from Cameron et al. (1955), *National Canners Association Bulletin.*

Retention of ascorbic acid in peas in their observations ranged from 47 to 82 per cent, the principal loss occurring during blanching. Niacin retention in peas ranged from 50 to 94 per cent.

Carotene was well retained in all products studied by these investigators. In the canning of whole-grain yellow corn they report the following average retention values: carotene 97 per cent, thiamine 34 per cent, riboflavin 97 per cent, and niacin 86 per cent. The averages for peas were ascorbic acid 72 per cent, carotene 97 per cent, thiamine 54 per cent, riboflavin 82 per

cent, and niacin 65 per cent. The average retentions for green beans were ascorbic acid 55 per cent, thiamine 71 per cent, riboflavin 96 per cent, niacin 92 per cent, and carotene 87 per cent. For asparagus the average retention values were ascorbic acid 82 per cent, thiamine 67 per cent, riboflavin 88 per cent, and niacin 96 per cent.

The ascorbic acid content of raw green asparagus and of Blue Lake green beans decreased very rapidly during holding after harvesting. Data indicated that a similar decrease occurs in spinach if held too long after cutting.

The canned vegetables decreased in content of ascorbic acid in storage after canning, much more rapidly at 80°F. than at 50 and 65°F. Losses for carotene, thiamine, and riboflavin during storage were much less than for ascorbic acid.

Soups. While the canning of soups, including vegetable, is a very important industry, soups are in the nature of specialties and usually contain meat stock or cream or other "nonvegetable" products, and on that account, as well as lack of space, they are not included in this book. See "Complete Course in Canning" for formulas, listed in references at the end of the chapter.

Dietetic Canned Vegetables. Most canned vegetables are of low-calorie content and on that account are of value as filling but nonfattening foods in reducing or other low-calorie diets. Tomatoes, asparagus, green beans, carrots, and spinach are especially useful in this regard. Cameron et al. in the *National Canners Association Bulletin* on dietetic canned foods give the calorie content of these five vegetables as ranging from 17 to 36 calories per 100 grams, in most cases below 25 calories per 100 grams. Canned peas, according to this bulletin, contain about twice as many calories per 100 grams, and canned corn about three times the calories furnished by the five vegetables mentioned above.

Several canned vegetables are low in carbohydrate content and on that account are useful in diets for diabetics. According to the authors of the *National Canners Association Bulletin* mentioned above, canned tomatoes have an average of 4.1 per cent carbohydrates, asparagus an average of 2.1 to 2.6 per cent, green beans 3.1 per cent, carrots 4.2 per cent, and spinach 2.9 per cent, average. Corn, white potatoes, sweet potatoes, and Lima beans are of as high to considerably higher carbohydrate content.

The vegetables listed above as being low in calories and carbohydrates are valuable sources of bulk in the diet. Most vegetables are not very low in sodium content, but several are good sources of potassium, an element that is, however, not usually lacking in the average diet. Sauerkraut, spinach, and turnip greens contain considerable amounts of iron, although there is some doubt concerning its availability in spinach because of its oxalate content. Vegetables on incineration give a basic ash and on diges-

tion and utilization in the body a basic residue that should tend to neutralize or counteract the acid ash of meats and cereal products.

Greens are rich in carotene, the precursor of vitamin A. Cabbage, cauliflower, and spinach are rich in vitamin C. All members of the cabbage family and greens are rich in riboflavin, vitamin B_2. See Cameron et al. (1955), H. J. Heinz Company "Nutritional Data," and books on nutrition for additional data on nutritional values.

REFERENCES

(See also list at end of Chap. 11.)

Baby foods in glass, *Food Packer*, **27**(9), 34–37, August, 1946, also August, 1949.

BITTING, A. W.: "Appertizing, or the Art of Canning," The Trade Press Room, San Francisco, 1937.

———: Methods followed in the commercial canning of foods, *U.S. Dept. Agr. Bull.* 196, 1915.

BLAIR, J. S., and AYRES, T. B.: Protection of natural green color in the canning of peas, *Ind. Eng. Chem.*, **35**, 85, January, 1943.

BURTON, L. V.: Measurement of maturity in Country Gentleman corn, *Canner*, Apr. 29, 1922.

CAMERON, E. J., CLIFCORN, L. F., ESTY, J. R., FEASTER, J. F., LAMB, F. C., MONROE, K. H., and ROYCE, R.: Retention of nutrients during canning, *Natl. Canners Assoc.*, 1955.

CAMPBELL, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. H. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

Canning peas in shortest time, *Food Packer*, **27**(10), 36–39, September, 1946.

Choosing a practical method for evaluating tomato color, *Canner*, **115**(26), 14–16, Dec. 27, 1952.

"A Complete Course in Canning," The Canning Trade, Inc., Baltimore, 1936.

Coordination in corn canning, *Food Packer*, **27**(12), 40–43, November, 1946.

Corn canning in Washington, *Western Canner and Packer*, **35**(12), 25–28, November, 1943.

CRUESS, W. V.: pH value and its role in food preservation, *Canner*, Mar. 17, 1945, pp. 24–27.

———, and LOW, D.: New canned Lima bean products, *Canning Trade*, **78**(25), 44–49, Jan. 9, 1956.

CULPEPPER, C. W., and MAGOON, C. A.: Factors affecting quality in sweet corn, *J. Agr. Research*, **34**(5), 413–433, 1927.

DESROSIER, N. W., FIELDS, M. L., and AMMERMAN, G. R.: Eight rules for preventing contamination of tomatoes, *Canner*, **121**(8), 14, Aug. 22, 1955.

DILLING, W. R.: Pallet boxes, *Canner*, **121**(21), 9–12, Dec. 26, 1955.

FARLEY, H. A.: Canning quality of spinach varieties, *Canning Trade*, September, 1929, pp. 16, 18, 20, 22.

FIELDS, M. L., AMMERMAN, G. R., and DESROSIER, N. W.: Rapid method of detection of vinegar fly eggs and maggots, *Canner*, **120**(26), 14–16, June 27, 1955.

FRIED, M.: Streamline corn husking operation, *Canner*, **117**(8), 15–17, 1953.

FROST, L. J.: The operation of retorts, *Continental Can Co., Research Dept., Bull.* 5, 1945.

GOFF, H. R.: Aseptic Canning, *Proc. Tech. Sess. 46th Ann. Conv. Natl. Canners Assoc.*, Feb. 28, 1953, pp. 7–9. (Also *Conv. Issue, Inform. Letter* 14.)

HANNA, G. C.: Asparagus production in California, *Univ. Calif. Agr. Ext. Circ.* 91, 1947.

HELSEL, PAUL E.: Development of sweet corn hybrids, *Western Canner and Packer*, **33**(12), 13–17, November, 1941.

High speed baby food operation, *Western Canner and Packer*, **38**(3), 55–59, March, 1946.

How 50 tons of corn are processed per hour, *Canner*, **117**(14), 14–17, Oct. 5, 1953.

HIRST, F., and ADAM, W. B.: The canning of green peas, *Univ. Bristol, Canning Research Sta., Canners' Bull.* 5, 1932.

HOLMQUIST, J. W., CLIFCORN, L. E., HEBERLEIN, D. G., and SCHMIDT, C. F.: Steam blanching of peas, *Continental Can Co., Research Dept.*, 1954.

JONES, H. A., and ROSA, J. T.: "Truck Crop Plants," McGraw-Hill Book Company, Inc., New York, 1928.

JOURNALS

Canner, Chicago, a weekly journal of the canning and freezing industries.

The Canning Trade, Baltimore, a weekly journal of the canning and freezing industries.

Food Engineering, New York, monthly journal covering canning, freezing, and other food industries. Formerly *Food Industries*. See also "Flow Sheets of Food Processes," a handbook published each year by this journal.

Western Canner and Packer, San Francisco, a monthly journal for the canning, drying, freezing, and related industries.

KERTESZ, Z. I.: Chemical determination of quality in canned peas, *N.Y. State Agr. Expt. Sta. Tech. Bull.* 233, 1935.

KRAMER, A.: Careful testing of peas for canning, *Canner*, **114**(14), 13–19, Apr. 5, 1952.

——— and SMITH, H. R.: The brine test for maturity of canned peas, *Canner*, June 22, 1946, pp. 14–17.

——— and ———: The succulometer for measuring corn maturity, *Canner*, June 1, 1946, pp. 11–12.

KUENEMAN, R. W.: Continuous agitating retorts, *Natl. Canners Assoc. Inform. Letter* 1426, Feb. 28, 1953.

LYNCH, L. J.: When to pick canning peas, *C.S.I.R., Div. Food Preserv. and Transport, Circ.* 5-P, Melbourne, Australia, 1955.

MACGILLIVRAY, J. H., MICHELBACHER, A. E., and SCOTT, C. E.: Tomato production in California, *Univ. Calif. Agr. Expt. Sta. Circ.* 167, June, 1950.

MARTIN, W. M.: "Aseptic Canning Process Embodying Short High-temperature Sterilization," W. F. and John Barnes Co., Rockford, Ill., 1951.

———: Flash process, aseptic fill, are used in new canning unit, *Food Inds.*, **20**, 832–836, 1948.

MERCER, W. A., and TOWNSEND, C. T.: "Water Re-use in Pea Canneries," *Natl. Canners Assoc., Research Lab., Bull.* 31-L, May, 1954.

MICHELBACHER, A. E., and MITTELKAUFF, W. W.: Vinegar fly investigations in Northern California, *J. Econ. Entomol.*, **47**(5), 1–8, October, 1954.

MONSON, H. G.: Vegetable cannery waste disposal, *Canner*, **116**(24), 14–17, June 15, 1953.

National Canners Association Research Laboratories: Annual Reports for 1950–1956, Washington, D.C.

———: Processes for non-acid canned foods, *Bull.* 26-L, 1955.

———: Dietetic canned foods, 1953.

———: Canned foods in human nutrition, 1950.

NORTON, C. E., and LEWIS, V. M.: "Notes on Canning Technology," Southern Can Co., Melbourne, Australia, 1951.

PEPPER, B. B., REED, J. P., and STARNES, O.: Drosophila as a pest of processing tomatoes, *N.J. Agr. Expt. Sta. Ext. Bull.* 266, 1953.

PILCHER, R. W., and ASSOCIATES: "The Canned Food Reference Manual," American Can Co., New York, 1949.

SAYWELL, L. G., and CRUESS, W. V.: Composition of canning tomatoes, *Univ. Calif. Agr. Expt. Sta. Bull.* 545, 1932.

SEATON, H. L.: "Scheduling Plantings and Predicting Harvest Maturities for Processing Vegetables," Continental Can Co., Chicago, 1955.

——— and HUFFINGTON, J. M.: Raw product quality control, Continental Can Co., *Research Dept., Bull.* 26, Chicago, 1951.

SMITH, C.: Packing processed foods in glass, *Canner*, **114**(23), 16–23, 29, June 7, 1952.

TISCHER, R. G.: Measuring the consistency of cream style corn, *Canner*, **114**(15), 12–19, Apr. 12, 1952.

TEISER, R., and HARROUN, C.: New efficiency in spinach processing, *Canner*, **116**(20), 14–16, May 18, 1953.

THOMPSON, R. C.: Asparagus culture, *U.S. Dept. Agr. Farmers' Bull.* 1646, 1954.

TOWNSEND, C. T.: Control problems posed by newer processing methods, *Canner* **114**(6), 15, 60–65, Feb. 9, 1952.

———, SOMMERS, I. I., LAMB, F. C., and OLSON, N. A.: A laboratory manual for the canning industry, *Natl. Canners Assoc., Research Lab.*, June, 1954.

———, YEE, L., and MERCER, W. A.: Inhibition of growth of Clostridium botulinum by acidification, *Food Research*, **19**, 536–542, 1954.

WOOSTER, H. A., and BLANCK, F. C.: "Nutritional Data," H. J. Heinz Co., Pittsburgh, 1949 (revised 1955).

CHAPTER 11

SPOILING OF CANNED FOODS

All canned foods, after sterilization, are subject to deterioration during storage. In many cases the changes that occur do not render the food unfit for consumption; nevertheless the appearance of the container or of the product may become so unattractive that it becomes unsalable. Two general types of deterioration are recognized: (1) spoiling by microorganisms, and (2) changes brought about by chemical or physical agencies. Microbiological spoiling of canned foods is the more important.

DEFINITIONS

Spoiled cans of food exhibit characteristic differences in appearance, taste, and odor from normal cans. The most common designations in use for the different types of spoiled or abnormal cans of food are given below.

Swell. A swelled can is one whose ends are tightly bulged from the formation of gas within the can by microorganisms and the ends of which remain convex and spring back to this position if pressed inward. Swelled cans of food are usually so badly decomposed as to be unfit for consumption. They may be poisonous because of the presence of *Bacillus botulinus* (*Clostridium botulinum*).

Hydrogen Swell. A hydrogen swell is caused by the formation in the can of hydrogen gas as a result of corrosion of the tin plate. The contents are usually sterile and often fit for food.

Springer. A springer may be merely a mild swell or a mild hydrogen swell; it may be caused by overfilling the can or by insufficient exhausting. Swells always pass through the springer stage. The ends, or at least one end, of a springer can be pressed in with the hand and will remain concave for a time. Springers, if caused by overfilling, underexhausting, or corrosion, can be used for food.

Flipper. A flipper is a can under very mild positive pressure. It may be of normal appearance, but the end, if struck sharply against the top of a table or other solid object, will become convex. It may represent the initial stage of a swell or hydrogen swell or, more frequently, be due to overfilling or underexhausting.

Flat Sour. A flat sour is a can of food which has undergone spoilage by microorganisms without gas formation and is normal in outward appearance. The product usually possesses a sour taste and frequently a sour odor. Vegetables frequently undergo this type of decomposition, which is usually a nonpoisonous change. Occasionally this condition is caused by bacterial spoilage before canning.

Leakers. Cans may leak because of (1) faulty seaming of the factory end of the can, (2) faulty seaming of the cannery end of the can, (3) faulty lock seaming, (4) pinholing by corrosion from the inside of the can or rusting of the outside of the can, (5) bursting of the can by excessive gas pressure developed in the can by decomposition, by microorganisms, or by formation of hydrogen gas through corrosion, and (6) by rough handling of sealed cans.

DISCOLORATION

Discoloration, while not so serious a cause of loss as spoiling by microorganisms, is nevertheless a problem for the canners of vegetables and some fruits.

Corn. There occasionally develops in canned corn a dark-green color throughout the product, or an inky-black, scalelike deposit on the interior of the can. The problem was investigated by Bigelow (1915) and his associates of the National Canners Association Research Laboratory. Their conclusions were that the uniform darkening of the entire contents of the can is due to the formation of copper sulfide and that the black deposit on the tin plate and small pieces of sulfide in the product is iron sulfide.

Copper Sulfide. It was found in the experiments of Bigelow and associates that as little as one part of copper per million parts of corn was sufficient to produce appreciable darkening. The trouble is most likely to occur during the first part of the canning season or after the plant has been shut down for a few days. The cause is the formation of a thin film of copper oxide or copper salts on the surface of copper kettles or other copper or brass equipment with which the corn comes in contact at some stage in the canning process. The copper oxide, or salt, dissolves and reacts with the hydrogen sulfide formed from the decomposition of the protein of the corn during sterilization. Stainless-steel equipment will prevent its formation.

Iron Sulfide. The formation of the black scale, or black pieces of iron sulfide, was once a much more serious problem than the darkening caused by copper salts. The sulfide is intensely black and is very finely divided; hence a relatively large amount of corn may be colored by a very small amount of this compound. It is not injurious to health, and only the appearance of the corn is affected. Fitzgerald, Bohart, and Kohman made an

exhaustive study of the problem and established the principal factors concerned.

Such was the status of the knowledge of this very costly form of deterioration in 1922. Bohart of the National Canners Association and research chemists of the American Can Company continued work begun by Bigelow and associates, concentrating their attention on the role of zinc compounds in preventing formation of iron sulfide. In 1924 Bohart published material on the preparation and use of a can enamel containing a small amount of zinc oxide. At present practically all canned corn is packed in containers lined with this enamel, which is commonly known in the industry as C-enamel, or corn enamel. A public-service patent was granted on this process. Any hydrogen sulfide formed during processing reacts with the zinc oxide in the enamel to give white zinc sulfide, which for the most part remains in the enamel without materially changing its appearance. In appearance it differs but little from the zinc oxide, as both are white in color and finely divided. At the low acidity of corn the zinc sulfide is stable; hence zinc does not go into solution to an appreciable extent. The enamel possesses a characteristic "dusty," or gray, appearance. Its use has solved the corn-black problem in very effective manner. The industry is greatly indebted to Bohart and those who worked on this problem with him.

C-enamel also is used for lining cans containing certain other foods prone to form hydrogen sulfide during processing.

Blackening of Peas. Peas sometimes develop a flaky black deposit similar in appearance to, and probably identical in composition with, the iron sulfide deposit in cans of corn.

It has been found that allowing the peas to undergo heating or sweating before canning increases the tendency to the formation of the black deposit. It is probable that the incipient decomposition which occurs under such conditions results in the formation of hydrogen sulfide from the breaking down of protein. It is therefore to be recommended that peas be canned as promptly as possible after harvesting.

Thorough washing and blanching before canning, it is believed, also reduce the tendency for formation of the black deposit. Use of cans lined with C-enamel prevents formation of the black deposit. Most peas are now canned in this type of can. Peas sometimes dissolve copper from unclean equipment, with a subsequent development of a black deposit of copper sulfide.

Black Deposit in Canned Fruits. Canneries in California during the 1921 season suffered some loss through the use of a grade of cane sugar known as "plantation granulated," in the manufacture of which sulfur dioxide is used. It is usually very light yellow or nearly white in color, is cheaper than refined sugar, and if free from sulfur dioxide can be used satisfactorily for peaches, other dark fruits, and berries. The experience of the 1921 season,

however, proved that it sometimes contains sufficient sulfur dioxide to cause serious blackening of the tin plate and in some cases the production of a hydrogen sulfide odor. The sulfurous acid reacts upon the plate and is reduced to hydrogen sulfide, which in turn reacts with the dissolved metals to produce a black deposit of metallic sulfide.

Sulfur from new sorting belts has occasionally caused a black deposit in canned fruits by reduction in the can to hydrogen sulfide and subsequent combination with iron to give iron sulfide.

Pink Pears and Peaches. If canned peaches and pears are not thoroughly cooled after sterilization, they will frequently become pink in color. It has also been claimed, but not proved experimentally, that overheating of the fresh fruit before canning, during shipment or storage, will result in the formation of a pink color after canning and that pears grown in very hot localities frequently develop a pink color after canning.

Pumpkin. Canned pumpkin frequently "detins" the container and causes the formation of a heavy black deposit, probably an iron and tannin compound, on the exposed steel surface. According to Huenick, the corrosion is due to the amino compounds of the pumpkin. The use of heavily lacquered cans prevents this trouble.

Apples. Apples will cause vigorous corrosion of tin plate if not thoroughly exhausted or otherwise treated before canning, to expel air from the can and from the fruit tissues. The dissolved iron may react with the tannin of the fruit to produce a black color.

Browning of apples before canning sometimes occurs. Placing the peeled and cut fruit in dilute brine and thorough blanching before canning will eliminate this type of discoloration.

Browning of Peaches. In cans of peaches sealed cold, darkening of fruit in the top of the can by oxidation may occur if processing is unduly delayed after the cans are sealed.

Sweet Potatoes. According to Kohman, the darkening of sweet potatoes is caused by a combination of the tannin of the potatoes with ferric iron compounds dissolved from the plate. Slack filling of the cans and the entrance of air through leaks permit corrosion and subsequent darkening of the potatoes to take place.

Darkening of Green Asparagus. Occasionally canned green asparagus, especially green tips, and the brine darken rapidly after the can has been opened. Ferrous iron is oxidized by oxygen of the air to the ferric condition and then reacts with an orthodihydroxy compound to give a very dark to even a black color ("ink"). Research in the Food Technology Department of the University of California and by the research staff of the National Canners Association indicates that the darkening may be caused by combination of ferric iron with a product of decomposition of rutin, a substance known to be present in considerable quantity in green asparagus.

One such breakdown product of rutin, viz., quercetin, has been shown to be capable of forming a dark compound with ferric salts. Research on the problem is being continued.

Darkening of Dried Fruits, Jams, Preserves, and Sirups. After long storage, dried fruits, marmalade, jams, jellies, and fruit sirups are apt to darken and become black through reaction between amino acids and hexose sugars (the Maillard reaction) and condensation of aldehydes derived from fruit sugars (see also Chapter 20, Packing of Dried Fruits and Vegetables).

CORROSION AND PERFORATION OF TIN PLATE

A large quantity of canned food formerly was lost annually because of corrosion and perforation of the tin plate, the greatest loss occurring with acid fruits, such as apples, plums, and berries, although perforation may also occur with less acid products, such as pumpkin.

Relation of Oxygen to Corrosion. H. A. Baker, one of the first to point out the relation between corrosion of tin cans and oxygen supply, found that the oxygen rapidly decreased in cans after sealing and sterilizing. His investigations indicated that the oxygen combines with the metal of the container, with the food, or with the nascent hydrogen formed by action of acid on the metal. He recommended that oxygen be excluded from the can as completely as possible by thorough exhausting and proper filling.

A number of years ago a cooperative series of investigations was made by representatives of the National Canners Association, the can manufacturers, and the steel-plate manufacturers. Investigations have also been made by various laboratories in America and in Europe. As a result of this research and of that on the general problem of corrosion of metals, we now have a much better understanding than formerly existed of the corrosion of tin containers by food products. The following section presents briefly several theories of metal corrosion.

General Electrolytic Theory of Corrosion. A brief discussion of the general electrolytic theory of corrosion of metals may serve as a suitable introduction to the corrosion of tin containers by canned foods.

When a piece of metallic zinc is placed in a solution of copper sulfate, the zinc dissolves and copper is deposited on the zinc, the copper being displaced by the more electropositive zinc. In chemical terminology, each atom of zinc loses two electrons to a copper ion, although in this simple case no electric current is generated.

However, a current will be generated if copper sulfate solution is placed in one container and zinc sulfate in another; the two containers are joined by a U tube filled with a salt solution, such as potassium sulfate; a rod of zinc is placed in the zinc sulfate solution and one of copper in the copper

sulfate solution; and the two metals are joined by copper wire. This current can be demonstrated readily and measured by a galvanometer. Zinc goes into solution, forming positively charged zinc ions and copper deposits on the copper electrode. Electrons given up by the zinc atoms flow through the wire and neutralize the positive charges on the copper ions, which then deposit as the metal. The salt solution in the U tube acts as an electrolytic conductor between the containers of copper sulfate and zinc sulfate solutions.

If a plate of zinc and one of copper are immersed in dilute sulfuric acid and joined externally by a wire, the zinc dissolves; electrons liberated by the zinc atoms travel through the wire as electric current to the copper electrode, where nascent H and hydrogen gas (H_2) are formed. In this case the zinc replaces the hydrogen ions of the dissociated dilute sulfuric acid. They "plate out" upon the copper as hydrogen atoms and, when a certain voltage is reached, are liberated as H_2. In this case the hydrogen is behaving as a metal. The zinc electrode becomes positively charged, the copper electrode negatively charged.

In these cases there is electrolytic corrosion of the zinc electrodes. In the electrolytic corrosion of metals it is not necessary that two different metals be involved. It is possible for two different areas of the same metal to form an electrolytic cell if one area is under greater strain than the other or if impurities are present.

Primary and Secondary Factors. The factors affecting the corrosion of metals may be divided into primary and secondary factors.

First of the primary factors is the normal potential of the metal, i.e., the electromotive force (e.m.f.) needed to prevent it dissolving against a normal solution of its ions; or it is the force tending to drive it into solution under these conditions. Sodium has a very high normal potential, and tin a low normal potential. The normal potential of hydrogen is placed at 0; the more electropositive metals, such as sodium, calcium, iron, etc., are above it in the electromotive series of the metals, and the more "noble" metals, such as copper, silver, gold, platinum, and others, are below it in this series. A metal high in this series will displace one lower in the series from solution.

The second primary factor is concentration of the ions of the metal in solution; the higher their concentration the less is the tendency for the metal to go into solution, i.e., to corrode.

The condition in respect to hydrogen overvoltage influences corrosion. Theoretically, hydrogen has a normal potential of 0 and should, therefore, be liberated as gas when it is displaced from solution by a metal. Actually, however, often a potential must be applied to the electrode to displace the hydrogen from the surface, this extra e.m.f. being termed overvoltage. Hydrogen under these conditions protects the metal and retards corrosion.

Hydrogen-ion concentration is another important primary factor. Thus,

the more acid the solution the more rapid should the corrosion be, if the hydrogen is removed as fast as it is deposited.

Pitting and consequent development of local cell action may be another primary factor.

There are relatively many secondary factors. Temperature is one of the most important of these. In the open, high temperatures may expel oxygen from the solution and thus retard corrosion; or if the solution is in hermetically sealed cans, high temperatures will greatly hasten corrosion.

Agitation hastens corrosion by continually removing the thin film of dissolved metal and bringing fresh solution in contact with the metal.

Depolarizers are extremely important; in canned foods they are substances that remove hydrogen from the metal surface and thereby make continued corrosion possible. Oxygen is such a depolarizer; it acts by converting the nascent hydrogen into water. Another is anthocyanin, a fruit pigment that is reduced by the nascent hydrogen.

Passivity, cessation of corrosion because of formation of a protective film, e.g., oxide on aluminum, may develop and stop corrosion.

Accelerators, such as sulfur in canned foods, may greatly hasten corrosion. Traces of this element enormously increase the rate of hydrogen formation in canned fruits.

Inhibitors of corrosion are known. There is said to be one such in beet sugar that retards the corrosion of tin plate.

The viscosity of the medium may in some cases affect the rate of corrosion; the more viscous the solution, the slower is the corrosion.

Purity of the metal is of great importance, since impurities may make possible local electrolytic cell action, thereby greatly increasing corrosion and pitting.

Corrosion is seldom uniform over the entire exposed surface of the metal, owing to surface variations in the composition or physical condition of the metal, local cell action, etc.

Hydrogen Overvoltage and Polarization. If an iron electrode is placed in a dilute acid solution, iron dissolves to give ferrous ions and displaces an equivalent amount of hydrogen ions, which give up their positive charges and deposit on the iron surface. The coating of hydrogen behaves as a metal and protects the iron against corrosion by opposing the deposition of additional hydrogen. If the iron is connected by an outside circuit to an electrode of another metal lower than it in the e.m.f. series, such as tin, then the iron for a time still displaces hydrogen ions and forms positively charged ferrous ions; and hydrogen is deposited on the tin. Unless the hydrogen is removed from the tin by imposition of an external voltage or by combination with oxygen or other depolarizer, the deposited hydrogen will exert an e.m.f. opposing further deposition of hydrogen on the tin, and thus further solution of iron. Eventually the reaction will cease. In other

words, the tin electrode becomes polarized. The extra voltage required to force the atomic hydrogen into the molecular gaseous form H_2 is the hydrogen overvoltage. In the iron-tin couple, or cell, H deposited on the tin may exert such a large back e.m.f. that the direction of flow of the electric current is reversed. In other words, tin will dissolve, and the iron becomes more "noble" than the tin.

Theories of Can Corrosion. As previously stated, when iron and tin electrodes are placed in a dilute organic acid solution, at first iron goes into solution and hydrogen plates out on the tin. In a short time sufficient hydrogen accumulates on the tin to exert a counter e.m.f. sufficient to prevent further dissolving of the iron. As iron has a lower hydrogen overvoltage than tin (a lower e.m.f. being required to evolve hydrogen from the surface of iron), there is then left only the iron surface for evolution of the hydrogen. Hence tin then dissolves, and hydrogen is liberated from the iron.

During the period when iron is dissolving, iron is anodic and the tin is cathodic; electrons, or "negative" electricity, flow from the iron electrode to the tin. During the second phase, while tin is dissolving and hydrogen is being liberated from the iron electrode, the current flows in the opposite direction to that of the first period. This reversal of the current was observed by Kohman and Sanborn.

Lueck and Blair attribute this reversal of current to the higher hydrogen overvoltage of tin compared to that of iron, which results in the condition outlined above. This is essentially the Lueck and Blair theory.

Kohman and Sanborn do not entirely agree with the Lueck and Blair explanation of the reversal of potential and give considerable weight to the inhibiting effect of tin salts in solution, in respect to corrosion of the iron. They also call attention to the precipitation of tin by proteins and other food compounds, which in that manner remove tin from solution and thus permit more tin to dissolve. They showed also that if oxygen is present to act as a depolarizing agent on the tin, iron continues to dissolve in canned apples and the can becomes perforated because small areas of the exposed iron of the tin plate are corroded through. Kohman showed that the addition to canned apples of the anthocyanin color present in the skins of apples, or the addition of logwood or quercitrin, greatly hastened the corrosive action of this fruit on tin plate.

Culpepper and Caldwell extended Kohman's work to other fruits and their pigments. They concluded that anthocyanin pigments not only act as tin acceptors, i.e., precipitate tin from solution, but also act as hydrogen acceptors, removing hydrogen as rapidly as it is deposited on the metal surface. On this account corrosion of the tin continues. Eventually much iron is exposed; local cell action ensues; iron becomes anodic and dissolves with evolution of hydrogen or perforation of the tin plate.

Morris and Bryan make the following statements: In the earlier stages of corrosion, the high hydrogen overvoltage of tin provides a very great protection against corrosion of the iron. Tin alone in the absence of oxygen is not attacked by fruit acids, but in the presence of iron it is attacked by these acids at a rate depending on the relative areas of the two metals. At low acidity, i.e., pH 4 or 5, attack on the tin plate is more rapid than at higher acidity. The evolution of hydrogen takes place at the iron surface during dissolving of the tin; probably much of the H_2 of hydrogen swells, in cases where severe detinning has occurred, results from this phenomenon. Any increase in the surface of iron exposed by detinning leads to increased corrosion of both metals. In lacquered cans, owing to the small areas of tin plate exposed, detinning is extremely rapid at low acidity. At very high acidity the tin is probably relatively immune to attack, and almost complete polarization exists.

Preventive measures are use of cold-rolled tin plate (Type L, etc.), thorough exhausting, effective sealing of the cans, acidifying of fruits of low acidity, avoiding presence of sulfur or sulfite in the sirup on the fruit canned, provision of ample head space for H_2, and storage of the canned food at low temperature.

Effect of Fill of Cans. Every means available should be employed to reduce the amount of air in the can, since oxygen accelerates the corrosion of tin plate. Filling the can as completely as is consistent with effective sealing reduces the head space and the volume of air contained therein; however, if the product is inclined to form hydrogen swells, the head space should be fairly deep in order to provide space for evolved hydrogen gas.

Preheating. Canned apples are particularly active on the plate. It has been demonstrated by Huenick, Kohman, and others that the pulp of this fruit contains a relatively large amount of air, which is not usually removed by exhausting in the usual manner. This fact explains the customary practice of preheating the prepared fruit before it is placed in the can. Several other methods of pretreatment are in use (Chapter 8).

The removal of air from apples by heating in dilute brine at 120°F. has been studied by Huenick, who finds that the following amounts of air are obtained from the fruit heated at 120°F. for the respective lengths of time indicated. The volumes of air are expressed in percentages of the total volume of the fruit. Heating for 20, 60, 120, 180, and 240 min. yielded 8, 8+, 9, 10, and 12 per cent of air, respectively. He recommends 20 min. heating at 120°F. as sufficient for practical purposes, as higher temperatures cause browning, but the fruit may be held at this temperature overnight without injury. Dilute brine (3 per cent salt) is preferable to water, because slight browning of the edges of the pieces is liable to occur in water. The air may also be removed by subjecting the fruit to a high vacuum in a liquid

such as water or dilute brine. Kohman recommends storage of the fruit for several hours in warm dilute brine to permit removal of the oxygen in the tissues by respiration.

Exhausting. Thorough exhausting of canned fruits serves the same purpose as preheating, viz., the expulsion of air from the fruit and liquid. A long exhaust at a moderate temperature is much more effective in expelling air than a short exhaust at a high temperature.

Usual Method. The usual style of exhaust box is heated by live steam, which gives a relatively high temperature, usually above 200°F. If open cans of fruit are subjected to a long period of exposure to the direct steam, the fruit in the top of the can becomes softened. If softening is avoided by a short exhaust, 2 to 4 min., air is not effectively expelled, even though the liquid in the center of the can may reach 165 to 175°F., because this short period of heating does not heat the fruit thoroughly.

An improvement over the usual method of exhausting consists in placing lids on the filled cans, clinching the lids to the cans by passing them through the first rolls of a double seamer, and exhausting the cans in hot water. This method permits escape of air from the can but prevents direct contact of steam with the fruit.

Exhausting in Water. Exhausting in water at 185 to 190°F. permits of more careful control and does not result in softening of the fruit in the top of the can. Bigelow (1922) recommended a 6- to 8-min. exhaust in a hot-water exhaust box about 20 ft. long and wide enough to permit ten No. 2 or six No. 10 cans to be carried abreast through the box by means of a suitable belt. The water level is at about 1½ in. below the tops of the cans and is maintained at 180 to 190°F.

Vacuum in Cans. Bigelow recommended that exhausting should be so conducted that the vacuum in the cans after sterilizing and cooling to room temperature will be for No. 10 cans about 8 in., for No. 3 cans 12 to 15 in., and for No. 2 cans 20 in. At present a somewhat lower range of vacuum is attained in cans of No. 2½ size and smaller. Some canners desire a vacuum of only 5 in. in a No. 10 can. If the vacuum is much in excess of the above amounts, the cans may show excessive paneling, and if the vacuum is much less, it may indicate the presence of an excessive amount of air.

Vacuum Sealing. It is possible to remove air from fruit and liquids by treatment under a high vacuum. It is also possible to seal cans *in vacuo.* Therefore canned fruits and vegetables can be thoroughly exhausted under a vacuum and vacuum-sealed without use of the usual method of exhausting by heat. The method is already in use for brineless corn, juices, canned dried prunes, spinach, some fresh fruits, coffee, and salmon and is also being used semicommercially for a number of other products.

Sealing in an Atmosphere of Steam. As mentioned previously, it is now customary in many canneries to omit exhausting of the filled cans in steam

and, instead, to seal the cans in an atmosphere of live steam. If this method is properly conducted, a good vacuum is usually attained. If, however, the product contains a large amount of dissolved and occluded air or other gas, prevacuumizing of can and contents is necessary. Fruits are now vacuumized before steam-flow seaming (Chapters 6 and 8).

Sealing in Inert Gases. A process of checking corrosion was developed in New York by Rector and Tenney and described in *The Canning Age*. The filled cans are first subjected to a vacuum to withdraw air, a neutral gas (CO_2) is admitted, and this gas is then removed under a vacuum and fresh gas is again admitted. This process is repeated several times, and the can is finally sealed with the neutral gas filling the head space of the can. The process was developed primarily for dry or semidry products, but it is stated that it can also be applied successfully to foods packed in sirup or brine. The pressure inside the can is equal to atmospheric pressure, and for this reason the tendency to form leaks is reduced. The neutral gas used does not favor corrosion. During the Second World War, dehydrated carrots and cabbage in 5-gal. cans were vacuumized and the space was filled with carbon dioxide. Nitrogen is sometimes used to fill the head space of canned orange juice and has been used in other canned foods.

Importance of Effective Sealing. Not only must the air be effectively removed from the can and contents before sealing, but its entrance must be prevented after sterilization by perfect sealing of the cans.

Cans equipped with paper gaskets may be sealed tightly enough to exclude microorganisms but still admit air slowly. The gasket in such cases acts as an air filter, and such cans are commonly known as "breathers." Rapid corrosion usually follows. Paper gaskets are now seldom used for canned foods.

The rubber-composition gasket is less apt to permit air to enter, but if imperfectly sealed, admits not only air but microorganisms as well. Imperfect sealing therefore becomes evident at once by the appearance of swells and bacterial spoiling.

Effect of Temperature of Storage. Like all other chemical reactions, the rate of corrosion of tin plate is more rapid at high than at low temperatures, and the storage of canned fruit in hot warehouses is therefore to be avoided.

Cooling. If the cans are packed into boxes while still hot or stacked closely together in the warehouse before cooling, they remain warm for several days, with consequent excessive corrosion. Prompt cooling is therefore advised.

Effect of Character of Tin Plate. Ordinary dipped tin plate is known as "coke plate" and carries about 1½ lb. of tin per base box. A grade of tin plate known as Charcoal-A, or Char-A, carries about 2½ lb. of tin per base box, and for very acid products it is to be preferred to the coke plate. A special cold-rolled plate known as Type L plate (or by similar names) has

been perfected and generally adopted. It is purer than ordinary plate, softer, and more homogeneous. It is very resistant to corrosion.

Since the Second World War electrolytic tin plate has come into very general use. Usually it has a much lighter coating of tin than plate tinned by hot dipping. A common electrolytic tin coating is 0.5 lb. of tin per base box. This is satisfactory for most vegetables and other foods of low acidity. For fruits the inside surface of the can ends is enameled. The coating for the outside surface of many cans is 0.25 lb. of tin per base box (see also Chapter 2).

It has been recognized that the tin coating is not perfect and that rather numerous small areas exist in which the steel plate is exposed; usually these exposed areas are very small. Bigelow stated that there are hundreds of these exposed areas on the surface of a single can and that increasing the weight of the tin coating does not eliminate these exposed areas.

The coating of the tin plate with lacquer, while it reduces the total amount of tin that goes into solution, greatly increases the tendency for the formation of pinholes. Kohman attributes this condition to slow disappearance of the oxygen in the lacquered can, with consequent prolonged contact of the acid juice and tin with oxygen. In the plain tin can the oxygen rapidly combines with the tin plate over a wide surface, or combines with hydrogen, and action is therefore not excessive at any one point.

Testing Tin Plate. It is sometimes desirable to test tin plate in order to determine the completeness of the coating of the steel plate with tin. This can be done by filling several cans with the following solution: water 1 gal., concentrated hydrochloric acid 1 cc., potassium ferricyanide 5 grams, and enough gelatin to cause jelling of the solution on cooling. A blue color will develop where the steel plate is not coated with tin.

Tin in Canned Foods. All canned foods contain some tin in solution or in combination with the product. At one time a Federal regulation placing the maximum tin content of canned foods at 300 mg. of tin per kilogram was enforced, but at the present time food-inspection officials do not attempt to apply the rule rigidly.

It has been proved by Bigelow and others that most of the tin in such foods is not to be found in the liquor but in the drained solids. The analyses of Table 25 taken from Bigelow's published results will indicate the relation of the tin content of the liquor and the solids.

Asparagus after 8 months' storage contained 280 mg. of tin per kilogram and after 31 months, 470 mg.; Lima beans after 9 months' storage contained 80 mg. of tin and after 33 months, 173 mg.; wax beans contained after 3 months 93 mg., and after 30 months, 347 mg. of tin per kilogram.

Storing Foods in Open Cans. Many housewives and others firmly believe that food stored in an open tin can overnight contains dangerous amounts of tin. In *National Canners Association, Research Laboratory, Bulletin* 2,

TABLE 25. TIN CONTENT OF SOLIDS AND LIQUOR FOR SEVERAL IMPORTANT CANNED FOODS
(Tin reported in milligrams per kilogram, or parts per million)

Product	Tin in liquor	Tin in drained solids	Total tin
Cherries	52	163	107
Cranberries	33	254	170
Raspberries	39	294	194
Peaches	86	251	193
Pears	99	151	130
Plums	43	180	125
Shrimp	67	381	224
Spinach	35	131	86
Asparagus (1 year)	252	489	433
String beans (1 year)	97	442	299

SOURCE: After Bigelow.

Bigelow reports the results of a number of experiments on the rate of solution of tin by various products in open cans. Some of the data appear in Table 26.

TABLE 26. RATE OF SOLUTION OF TIN DURING STORAGE OF FOOD IN OPEN CANS
(In milligrams per kilogram)

Product	Tin on opening	Tin after 1 day's storage	Tin after 2 days' storage	Tin after 3 days' storage
Apples	59	81	91.5	129
Corn	12	15	14.0	11
Sauerkraut	44	51	74.0	113
String beans	144	138	143.0	160
Pumpkins	314	312	360.0	407
Tomatoes	68	69	93.0	143
Pineapples	75	97	102.0	158

SOURCE: After Bigelow.

The rather rapid solution of tin between the second and third days in some cases was due to fermentation or decomposition in other ways by microorganisms. In general it may be stated from these data that the amount of tin dissolved on standing in the open can is small and that any fear of food that has been left in the can overnight is unfounded.

Rusting and Corrosion of Outside of Cans. In the operation of steam boilers in canneries the water used for generation of steam is usually treated with an alkaline-boiler-water-treating compound which renders the boiler water alkaline in reaction. Under certain conditions some of the water

from the boiler may be carried over into the closed retort or open processing equipment in sufficient quantities to permit corrosive action of the tin coating or lithographed label on cans so labeled before retorting. It may be severe enough to merely cause spangling or graying of the tin surface, or be so severe as to detin portions of the tin coating, exposing the steel plate.

In cases of severe corrosion the appearance of the can surface may be so badly damaged that the canned product becomes unsalable. Rusting of the exposed steel surface may occur after removal of the cans from the retort.

Normal steam, free of boiler compounds, is usually neutral or slightly acid in reaction because it contains some CO_2; but if boiler compound is carried over in the steam or droplets of water, the condensate may be quite alkaline, with a pH of 8 to 9 or even higher. Tin coatings are soluble in a retort at such alkalinity. The detinning may occur only at points where the incoming steam hits the cans or in the condensate in the bottom of the retort. It can occur in steam-exhaust boxes from dripping condensate or direct contact of cans with the incoming steam. It can also occur in open prcoessors filled with water into which steam is injected to heat the water.

Rusting may occur at points where the cans are in contact with the metal of the retort basket, and this may be increased by electrolytic action set up between the tin of the can and the metal of the retort basket. A white deposit may be left on the cans from carryover of water from the boiler if it contains a large amount of insoluble carbonates and sulfates. These do not wash off during cooling in water after retorting and must be removed by rubbing, an expensive operation.

Overloading of the boilers increases the danger of carryover. The plant should have too much rather than too little boiler capacity. Filling the boiler to too high a level with water may bring the level too close to the steam outlet, thereby greatly increasing the danger of boiler-water carryover. The boiler should have an automatic water-feed system to maintain a safe and constant level of water in the boiler. Boilers can be equipped with a constant or continuous blowdown system that automatically rids it of excess insoluble compounds and reduces the danger of scale in steam lines and deposits on the cans. Or the retort should be blown down occasionally manually, if it is not equipped with a continuous blowdown system.

In addition to carryover due to surging, or "priming," of water from the boiler into the retort, foaming may be another factor. It is often caused by small amounts of lubricating oil from steam pumps or steam engines where the condensate is returned to the boiler.

Rusting of the outside of the cans may occur if they are overcooled after processing and cased damp or wet. Excessive treatment of the cooling water with chlorine may increase the tendency of the can to rust, or "spangle," as will abnormally high concentrations of organic acids such as

CO_2 and fruit acids in the cooling water. Brine or sirup in small amounts on the outside of the can from siruping or brining operations may cause rusting if too long an interval occurs between sealing of the cans and processing or if such contamination remains on the can after processing. Uncased cans may rust in the warehouse if condensation of water occurs through poor control of temperature.

Water high in suspended solids may require clarification before use in the boiler. Acid-regenerated zeolite softener, according to Schafer and Betz (1954), will remove compounds responsible for water hardness and alkalinity. Organic antifoaming agents are now available and, if properly used in the boiler, prevent or greatly minimize carryover due to foaming. Also, oil-separating devices can be placed in the water-feed line to the boiler to remove this hazard. Traps in the steam line are very valuable for removal of much of the boiler-water carryover before the steam reaches the retort.

Damaged Can Seams. Can seams may be damaged to the extent of causing leaks if the cans are handled very roughly in loading or unloading the retort baskets or in conveying the filled, sealed cans in runways from the double seamers to the retort or from the retort or can cooler to the casing station or warehouse. Leaky cans are very apt to admit spoilage organisms, with consequent spoilage of the can's contents. See a later paragraph on contamination of can contents during cooling in water.

Faulty double seaming of the filled cans (faulty sealing) may be a cause of leakers; but if such occurs, it is very apt to be due to careless operation and adjustment of the double-seaming machines. These are kept in perfect working condition in most canneries by mechanics assigned to that duty.

Corrosion Due to Undercooling. If the cans from the cooling system after retorting or other heat processing are cased too warm or stacked in the warehouse too warm, corrosion of the inner lining of the can is intensified and may greatly shorten the shelf life of the product. On the other hand, if the cans are cooled to too low a temperature before casing, they may remain wet or moist in the case long enough to permit rusting.

Discoloration in Glass-packed Sieved Foods. Several years ago canners of baby foods and certain other sieved foods packed in glass encountered the problem of slow darkening of the contents of the jar at and near the upper surface of the contents. Very thorough investigation by researchers of the glass manufacturers and canners showed that the trouble was caused by slow oxidation by minute amounts of air that entered the jar very slowly through the composition seal of the jar lid. The difficulty has now been overcome and is no longer a hazard, because a sealing compound has been developed that prevents inward leakage of air.

Corrosion of Metal Closures of Glass-packed Food Products. A number of years ago the packers of ripe olives encountered rather heavy losses

through corrosion of the metal caps of glass jars of ripe olives. Perforation of the caps occurred in severe cases, and pitting of the metal of the cap beneath the enamel coating occurred. Some other glass-packed foods also developed this form of corrosion.

Kohman and others at the Campbell Soup Company (1950) made an extensive study of this type of corrosion. They found that the blisters formed on the inside surface of the enameled lid were caused by accumulation of liquid beneath the enamel and that the liquid in the blisters contained a chloride content equivalent to a brine of 3.5 per cent sodium chloride but a sodium content equivalent to only 0.053 to 0.11 per cent sodium chloride. The ferrous iron content of the liquid in the blisters, however, was approximately equivalent to the chloride content. Kohman states that this evidence seems to prove that the pit under the blister is the anode of a galvanic couple. Secondly, the fact that there was no accumulation of hydrogen gas in the container indicated that the cathode of the couple lay outside the jar. It was concluded that the gasket allowed a film or capillary of electrolyte to be formed in the gasket through which the hydrogen ion or other positive ions such as sodium and potassium could travel to the outside surface where oxygen of the air could combine with the nascent hydrogen, or the metallic ions could be deposited and form carbonates. This phenomenon has been observed, Kohman states, with cans closed with lids containing paper gaskets. A crust of metallic salts accumulated outside the seam in cases where the gasket was not rolled on sufficiently tight. Occlusion of particles of the food product under the seam might act as an electrolytic conductor and thus promote this type of corrosion.

Kohman suggested that a cap fitted with a gasket containing a water-repellent material, or one coated with such material, be used in order to prevent capillarity. Capillarity might permit a film of electrolyte to form between the gasket and cap and reach the outer edge of the cap. Use of a gasket that will not itself conduct an ionic current is recommended. Also, entrapment of food particles in the seam must be avoided.

Evidently the closure problem has been solved by the glass-container-closure manufacturers, as baby foods are successfully packed and marketed in glass containers at present and in very large quantities.

Unsatisfactory Color of Certain Fruits in Enameled Cans. Peaches canned in enamel-lined cans with enameled ends are apt to be unsatisfactory in color, being dull or grayish in tint. In plain tin or in cans of which the bodies are of plain tin plate and the ends enameled, electroplated tin, the fruit has a bright, satisfactory color. Apparently, the slight reducing action of the metal in contact with an acid food product establishes a desirable color in the canned fruit.

Spray Residues. Many new spray materials have been developed in recent years for the control of insect pests of canning fruits and vegetables.

Among these several have come into commercial use. Lindane, DDT, malathion, and toxaphene are examples of the new spray materials. In general they are very toxic to insects, killing by mere contact. The Federal Food and Drug Administration, the National Canners Association research laboratories, and the University of California Entomology and Food Technology Departments have made and still have under way investigations on the rates of disappearance of various spray materials from the treated crops under field conditions, their removal by washing and other treatments in the food-processing plant, methods of analysis to determine or detect minute amounts of residues on food products, and the effect of certain insecticides on the flavor or odor of the canned, dried, or frozen product. Federal regulations and policy are affected by the provisions of the Miller bill enacted by Congress.

Amazingly small amounts of lindane used to control insects in the soil or on the fruit or vegetable are sufficient to impart a disagreeable flavor to the processed products. One method of detecting very small residuals of certain spray materials is by the fly bio-assay methods of the University of California and the Food and Drug Administration. An extract is made of the suspected sample, and its toxicity to flies reared under controlled conditions determined. Even very slight residues can be detected by this method. Very sensitive chemical-assay methods are also available. Baby foods, in particular, are subject to close and critical examination, both by the canner and the food and drug agencies. Full details of the methods can be obtained from the Entomology Department of the University of California, Berkeley, the National Canners Association Research Laboratories, Washington, D.C., and Berkeley, and the Food and Drug Administration, Washington, D.C. In some cases the Federal tolerance is very low for certain insecticide residues, or may be zero tolerance (no residue at all).

Off Flavors Due to Regeneration of Enzymes in Canned Foods. It was shown by Balls (1943), Schwimmer (1944), and others that the enzyme peroxidase has the power of regenerating some to much of its activity after being heated at temperatures below the boiling point a sufficient time to reduce its activity to a trace, or to zero in some cases.

More recently, high-temperature, short-time processing for the sterilization of food products in cans in agitating retorts or in the aseptic canning process in a heat interchanger at high temperatures have come into commercial use. In some cases off flavors have developed in the stored canned products, although they have been sterile in so far as bacterial activity is concerned. The research of Guyer and Holmquist (1954) and of Farkas, Goldblith, and Proctor (1956) have shown that peroxidase has great resistance to destruction by high temperatures. In other words, its resistance to high-temperature, short-time sterilization

procedures may be greater than that of many heat-resistant bacteria, although at temperatures at or below 212°F. it is usually destroyed by processing temperatures and times in commercial use in canneries; also in retorting practice followed for nonacid foods sterilized in still retorts, where the time is much longer than in the H.T.S.T. method.

In this regard, Farkas, Goldblith, and Proctor make the following statement:

> Most references cite regeneration below 100°C (212°F). But above this temperature it was found to be even more pronounced, occurring within a heating range of 6 sec. at 110°C (230°F) if activity was assayed without storage. Storage for 48 hours showed an activity of 64% of the original unheated preparation. Heating samples at 130°C (266°F) for 36 sec. reduced the activity to 6% after 24 and 48 hour storage; while in 5 days, activity had increased to 10% of the original preparation.

They used a liquid preparation of fresh peas and tested peroxidase activity with the well-known H_2O_2 guaiacol technique. If peroxidase is so resistant to H.T.S.T. processing, perhaps other enzymes may be also. At any rate, if this method is used it must be severe enough to destroy enzymes as well as the spores of spoilage organisms.

Using canned fresh peas, Guyer and Holmquist found that peas processed in an agitating retort at 260°F. for 4 min. had a strong "viny" flavor after one month's storage, a slight "viny" flavor when processed 5 min., but none if processed for 6 min. at 260°F.

MICROORGANISMS CAUSING SPOILAGE

The microorganisms encountered in the spoilage of canned and other food products are unicellular and are usually assigned to the vegetable kingdom, although they possess some characteristics that are intermediate between those of plants and animals. They are classified or recognized on the basis of various characteristics. For example, molds are usually classified according to macroscopical and microscopical appearance of their pure cultures, habit of growth of the mycelium, method of formation of fruiting bodies or spores, and related morphological characteristics. On the other hand, many bacteria resemble each other very closely in appearance of their cultures in test tubes or on nutrient agar and in their appearance under the microscope, but have very different properties in respect to their products of metabolism, their effects on various carbohydrates, oxygen requirements, etc.

Yeasts more nearly resemble molds than they do bacteria in their growth characteristics, effects on carbohydrates, and in some other respects; but like bacteria, different species very often resemble each other

very closely in microscopical appearance of the cells and in gross appearance in pure culture.

Molds

Molds are distinguished by the formation of a mycelium, which is a network of filaments or threads. These threads are termed "hyphae" (singular, hypha) and are usually visible to the unaided eye.

Molds differ from each other principally in their methods of producing spores and conidia, but there are also easily recognizable differences in the appearance of the mycelium and in the nature of the chemical changes induced in media suited to their growth. Variations in external and microscopical appearance, however, are not always reliable for identification and classification, as the appearance is often affected profoundly by circumstances. Sometimes the mycelial cells form compact masses of rather firm texture, as in mushrooms. Such a mass, which becomes dry and firm with thick hard walls, is called a "sclerotium." Some fungi form a mycelium without cross walls (nonseptate), and the mycelium is termed "nonseptate," or "coenocytic." These molds are also termed "Phycomycetes." The other fungi possess a septate mycelium.

Some molds form yeastlike cells under certain conditions and may even induce feeble alcoholic fermentation, as in some of the Monilia and Mucor molds.

Molds are also grouped as Basidiomycetes, which include mushrooms, puffballs, and bracket fungi; the Ascomycetes, which include many of the septate molds and spore-forming yeasts; and the Fungi Imperfecti, which do not exhibit the complete life cycle of the Ascomycetes. The spores of the Ascomycetes are enclosed in an ascus, or sac. The Fungi Imperfecti include most of the penicillia, certain other molds, and several species of yeasts.

Penicillium. Molds of the *Penicillium* group are the most common and most troublesome to the manufacturer of fruit and vegetable products. C. C. Thom of the U.S.D.A. has made an exhaustive study of the *Penicillium* molds.

In the initial stages of growth, *Penicillium* is white and cottony in appearance. Later, spores, or conidia, are formed in enormous numbers and give a powdery appearance to the growth, which is blue, brown, or pink, according to the color of the conidia and the age of the growth.

P. glaucum, or, more correctly, *P. expansum*, is the best known of the *Penicillium* molds and the one responsible for very great losses to fresh-fruit shippers and fruit-products manufacturers. Unfortunately, this term has been applied to many green forms of *Penicillium*, a large proportion of which are not *P. glaucum*. Thom makes four main subdivisions of the

penicillia. These are the Monoverticillata, with a single whorl of spore-bearing sterigmata; the Biverticillata-symmetrica, with two whorls; the Polyverticillata-symmetrica, with several whorls symmetrically arranged; and the Assymmetric, with whorls assymmetrically arranged.

Penicillium glaucum. This species is objectionable principally because of its very disagreeable "moldy" odor and flavor. In young cultures the growth is white and filamentous. The color later turns to blue or green with the formation of spores and in old cultures becomes brown. The spores, or conidia, are spherical in shape and are formed in great abundance upon upright hyphae or conidiophores. The conidiophores are branched only in the upper portion. The fructifications consist of a complex system of branches, the ultimate fertile cells of which produce chains of conidia by constriction.

The conidia are light and are carried by air currents. They are universally distributed on surfaces and in the air; all fresh fruits and vegetables carry spores of this organism on their surfaces. This mold will grow on practically all food materials exposed to the air, if the conditions of moisture content and freedom from antiseptics permit the growth of any micro-organism. It prefers sugar-containing substances such as fruits, fruit juices, jams, etc., but will develop on such unpromising material as moist leather. Any acid material affords a more favorable medium for growth than does an alkaline or neutral medium.

Growth is most abundant at temperatures ranging from 15 to 25°C. but will occur at temperatures near the freezing point, 0°C., and slowly at temperatures of 35 to 37°C.

Other Penicillia. Other important penicillia are *P. italicum* and *P. digitatum* (also called *P. olivaceum*), which cause decay of citrus fruits; *P. rocquecforti Thom*, *P. camemberti* used in making rocquefort and camembert cheese; and *P. brevicaule,* well known for its ability to form diethylarsene, a substance of garliclike odor from arsenic compounds. Some *Penicillium* molds form citric acid but have been displaced by *Aspergillus* for this purpose industrially, since it is more productive and efficient. Others are used industrially in the manufacture of gluconic acid.

Aspergillus Molds. Another very common group of molds often seen on grapes and other fruits are the *Aspergillus* molds (aspergilli). The conidia, or fruiting cells, are borne on upright conidiophores that terminate in abrupt enlargements from which spring spikelike projections called sterigmata that bear long chains of conidia. *Aspergillus niger* is the best known of these molds. Its growth at first resembles that of *Penicillium*, being white and cottony; but after the conidia are formed in abundance, the growth becomes black in color; hence its name *niger*. It is well known for its ability to form oxalic acid from sugar and, under proper conditions,

citric acid. It is used commercially for the production of citric acid. It may grow in or on insufficiently sterilized fruit juice, jelly, or jam.

Another well-known and industrially used *Aspergillus* is *A. oryzae.* It is used in the Orient to convert the starch of rice into sugar, which is then fermented by special yeasts to give an alcoholic beverage known as sake. Many other species of *Aspergillus* have been described.

Mucor Molds. The "pin molds," or Mucor molds, are also very common. They often develop on moist, stale bread, and some species are known as bread molds on that account. The conidia, or spores, are borne in pin-headlike sacs, sporangia, on the ends of long aerial threads known as sporangiophores. The mycelium is unicellular, i.e., nonsegmented, or coenocytic. Several have been used to hydrolyze starch to sugar for the production of industrial alcohol. They may cause molding of berries in transit or storage but are seldom encountered in or on processed fruit or vegetable products.

Parasitic Molds. All the foregoing molds are saprophytic, i.e., grow on nonliving media. In addition, there are many molds and moldlike organisms that grow on or in living plant tissues. *Sclerotinia fructigena*, for example, in wet weather often grows on various fruits on the tree or in boxes to cause brown rot. Another one causes a mildew of grapes and grape leaves. Other parasitic molds cause wilt and other diseases of various vegetables, including tomatoes and potatoes. The damage done is usually on the tree or on the vine, rather than to the raw material en route to the cannery or to the canned or otherwise processed product.

Yeasts

True Yeasts. Yeasts differ from molds in that they permanently maintain a unicellular habit of growth and do not form a true mycelium. They differ from bacteria in that they usually multiply by budding instead of by fission; a few yeasts are an exception to this rule, however. Many yeasts are powerful fermenters of sugars to alcohol and carbon dioxide and on that account are of great importance in the production of such fruit products as wines and vinegars. They are also used in the making of bread and beer and in the fermentation of various raw materials for the production of industrial alcohol and distilled beverages of various kinds. Many others have little or no industrial utility; some grow on pickle brines or fermented apple juice as heavy films and are considered spoilage organisms in such cases. Some, such as the Hansenula yeasts, form large amounts of aromatic esters.

Yeasts may be grouped as industrial yeasts and as wild, or nonindustrial, yeasts; or as true yeasts that form spores and the pseudo yeasts, which

are nonsporulating; or as bottom yeasts and top, or film, yeasts. The terms "true yeasts" and "pseudo yeasts" are more common than the others mentioned above.

In the fruit-products industries the *Saccharomyces* group is of greatest importance, as its members are used in the fermentation of fruit juices for the production of wines and vinegar. Also, they are usually involved when a leaky can of fruit ferments with the production of carbon dioxide and alcohol or when a poorly pasteurized jar of jelly or jam undergoes fermentation. Wine yeast is generally known as *Saccharomyces ellipsoideus*, although it is also classified as *Saccharomyces cerevisiae*, var. *ellipsoideus*. Its cells are of medium to large size and oval to ellipsoidal in shape when viewed under the high power of the microscope. The cells form spherical spores under proper conditions, two to four spores per cell. The spores are considered to be the resting stage of the organisms and are more resistant to adverse weather or storage conditions than are the vegetative cells. *S. ellipsoideus* is a vigorous fermenter capable of producing as much as 18 per cent of alcohol in grape juice of sufficient sugar content. Microbiologists interested in wine making, in Europe particularly, have selected strains of this group of yeasts especially suitable for Champagne making; others for fermentation at the low temperatures often prevailing during the wine-making season in Switzerland, the Rhine district of Germany, and in the Burgundy region of France. In California the strains known in the industry as Champagne Ay, Burgundy, and Tokay are the most common for use in wineries and vinegar factories. In the making of Spanish-type "flor" sherries a group of wine yeasts closely related to *S. ellipsoideus* is used. They are characterized by their ability to grow on the surface of white wine of high alcohol content in butts or small tanks with the production of the characteristic bouquet and flavor of Spanish sherries. They are also powerful fermenters; in experiments in the author's laboratory 19 per cent alcohol has been formed by one strain of these yeasts. They have been classified as *S. sheresensis*. *S. ellipsoideus* is found occurring naturally on grapes and other fruits.

Beer yeasts belong to the *Saccharomyces cerevisiae* group. Bread yeast and some distillery yeasts are also members of this species. Their cells are usually somewhat larger than those of *S. ellipsoideus* and are apt to be spherical or egg-shaped in outline under the microscope. The beer yeasts generally do not form as much alcohol in a medium rich in sugar as do the *ellipsoideus* yeasts and are better adapted to fermentation at low temperatures. *S. ellipsoideus* usually produces a "vinous" flavor and odor in fermented liquids, whereas the *cerevisiae* beer yeasts are prone to give a beerlike flavor and odor. The distillery yeasts usually have high-alcohol-forming power and are more rapid fermenters than the beer yeasts. Bread yeasts resemble the distillery yeasts.

Other culture, or industrial, yeasts are *S. sake* used in making a cereal beverage of this name and *S. malei* employed in making certain types of hard cider.

Other true yeasts worthy of mention are *Zygosaccharomyces*, which has been found in soybean sauce, raw sugar, beer, and orange sirup and is noted for its peculiar method of sporulation, in which two cells are joined before spores are formed; *Saccharomyces pyriformis*, found in ginger beer; *S. pasteurianus*, a wild yeast that occasionally develops in fermenting fruit juices with production of a bitter taste; *Hansenula*, a film-producing wild yeast that forms hat-shaped spores and produces large amounts of aromatic esters; and *S. ludwigii*, a yeast that forms large cells many of which are lemon-shaped. It is occasionally found in fermenting apple juice. *Pichia* yeasts are film-forming true yeasts that are often found on pickle brines.

Pseudo Yeasts. Like the true yeast group, the pseudo yeasts contain many members. They do not form spores. Practically all of them are undesirable in the fermentation industries because of production of off flavors and cloudiness. One of the most important is *Torula*, which includes many yeasts of different properties, but having in common the properties of growing as bottom yeasts and the inability to form spores. One is well known to most elementary students in bacteriology as it often grows on agar plates as a contaminant; it is red in color and easily recognized. Another is *T. kephir*, used in making a milk beverage of the same name, and differs from most yeasts in its ability to ferment lactose. *Torula* yeasts are often encountered in brewing and may be used in the secondary fermentation of some types of beer or stout. *T. amara* causes a bitter taste in cheese and milk.

Apiculatus yeasts are often found in naturally fermenting fruit juices. The cells are small, and many are lemon-shaped when viewed under the high power of the microscope. Most apiculate yeasts do not form spores and are known as Hansenia yeasts. Several apiculate yeasts, however, do form spores and are true rather than pseudo yeasts. Both types may produce off flavors in wine and cider.

Mycoderma yeasts are very common in wineries, vinegar factories, pickle works, and olive-pickling plants. They form white and sometimes wrinkled films on hard-cider-vinegar stock, pickle brines, and wines of low alcohol content if these are exposed to the air. The yeast is very aerobic; consequently one good method of preventing its growth is to fill the tanks of wine, vinegar stock, or other susceptible product completely and seal them effectively against entrance of air. The *Mycoderma* and certain other film yeasts are strongly oxidative in their effect on organic acids, alcohol, and other organic constituents of fermented liquids and pickle brines and may reduce the total acidity to the point at which putrefactive

bacteria may grow; or they may so change the composition of the product that it is worthless. In other words, if not controlled they can cause spoilage.

Bacteria

General Properties of Bacteria. From the canner's standpoint bacteria are much more important spoilage organisms than are yeasts and molds, as their spores are often very resistant to heat. However, most bacteria cannot grow in canned acid fruits such as peaches, apples, apricots, and plums because of the low pH value or are easily destroyed by heat in such products. They grow readily, however, in nonacid canned foods such as most vegetables, meat products, fish, and milk or milk products.

Like the yeasts and molds they may be classified in several different manners. Many bacteria are motile when viewed under the microscope. Townsend and Esty have given several useful definitions, as follows: Coccus—a spherical bacterial cell. Bacillus—a rod-shaped bacterial cell. Coccobacillus—an oval-shaped bacterial cell. Aerobe—a microorganism requiring atmospheric oxygen for growth. Obligate anaerobe—a microorganism that will not grow in the presence of atmospheric oxygen. Facultative anaerobe—grows with or without atmospheric oxygen. Mesophile—a microorganism requiring moderate temperatures for growth (below 100°F.). Obligate thermophile—a microorganism requiring temperatures for growth between 100 and 180°F. Facultative thermophile—grows over the whole range of temperature covered by mesophiles and obligate thermophiles.

Limitations of space will not permit a full description of all the bacteria of importance to food processors, and on that account only a few of the more important will be discussed as examples. An excellent reference on these microorganisms in Tanner, "Microbiology of Foods."

Bacterium Aceti. Vinegar bacteria are spoilage organisms in the wine industry but useful and necessary in the production of vinegar. They are very small, very short rods, usually nonmotile, and usually do not form spores. They are aerobes and can use several carbohydrates as substrates although their favorite source of energy is ethyl alcohol, which they oxidize to acetic acid if oxygen is provided. There are two types in respect to method of growth; one forms a tough shiny film on wine or hard cider, this growth being known as "vinegar mother"; the other type grows throughout the wine, or cider, or other alcoholic liquid without forming vinegar mother. Vinegar bacteria are easily destroyed by heat, usually at 65°C. Because of this fact and their need of oxygen for growth they are not involved in the spoilage of hermetically sealed foods preserved by heat. They do, however, cause the souring of fresh figs that have been infected with yeast and vine-

gar bacteria. Their industrial use is covered in the chapter on vinegar making.

Lactic Bacteria. An important group of bacteria are the lactobacilli (lactic bacteria). It is a rather heterogeneous group, as it includes organisms of very different properties, although all members produce appreciable amounts of lactic acid from various sugars. Those used in the brewing and distilling industries are heat-tolerant, facultative thermophiles that grow abundantly at 50 to 55°C. and form lactic acid rapidly in that temperature range. Others, which are mesophiles, are used in the fermentation of pickles and sauerkraut. *L. plantarum* is a well-known lactobacillus found in pickles and green olives. It grows in the form of long, nonmotile rods.

When lactobacilli occur in wine and cider-vinegar stock they are considered to be spoilage organisms. The bacteria in this case are usually long rods resembling *L. plantarum* under the microscope. Lactic souring of wines is well known, although easily prevented by maintaining a moderate concentration of SO_2 in the wine.

The lactic bacteria responsible for the making of cheese and souring of milk and cream differ in microscopical appearance from those used in the curing of pickles. They are usually short rods. They transform lactose into lactic acid. The lactic bacteria of pickles, wines, and milk products are easily killed by pasteurization; hence they are of minor concern in heat-processed canned and bottled products.

Incidentally, the thermophilic bacteria that cause flat souring of canned nonacid vegetables also form a small amount of lactic acid, but are seldom classified as lactic bacteria.

Thermophiles. As indicated by Townsend and Esty, thermophiles are placed in two groups, viz., obligate thermophiles which grow only in the range 100 to 180°F. and the facultative thermophiles which grow at temperatures below 100°F. as well as at higher temperatures. Each group contains organisms that produce flat-sour spoilage of canned foods and those that form gas, causing the affected can to swell. Some are obligate anaerobes; others are facultative anaerobes. A few thermophiles form H_2S, which imparts a vile odor to the spoiled food and combines with small amounts of dissolved iron in the affected canned food and the iron of the base plate to give black FeS. This organism is rare, nevertheless has caused several extensive outbreaks of canned-food spoilage.

Thermophiles form heat-resistant spores, in some cases of amazing resistance. Survival times of over 30 hr. at 212°F. and of more than an hour at 250°F. have been reported. Consequently, if a canned food of low acidity is heavily contaminated, it is impossible to destroy the spores with any heat process that will give a merchantable product.

Most thermophiles are inhibited at pH 4.7 or lower, although *B. thermoacidurans* will develop readily in tomato juice of lower pH.

Thermophile spores occur nearly everywhere in the soil; but in canned peas and corn the main thermophilic contamination is from build-up of the organisms in "hot spots" in the cannery, as is pointed out later in this chapter. Asparagus, on the other hand, is often heavily infected by soil-borne thermophiles as it grows in the field. Sugar in the past has been a source of thermophilic spores causing initial contamination of such equipment as corn and pea wooden hot-brine tanks, sirup tanks, pipelines, etc. Sugar may contain the spores because opportunity may be given for growth of thermophiles at certain stages of sugar manufacture. The National Canners Association research laboratories have established the following method of sampling of sugar deliveries and tolerances for spores in sugar used in canning of nonacid vegetables.

A sample of ½ to 1 pound shall be taken from each of 5 bags of sugar in the delivery. There shall be a maximum of not more than 150 spores per gram of sugar in any one sample and an average of less than 125 per 10 grams for the 5 samples. Gas formers may be present in not more than 3 of the samples and to the extent of not more than four of the six tubes of medium inoculated by the standard procedure. Sulfide thermophiles shall be present in not more than two of the five samples and in any one sample to the extent of not more than five spores per 10 grams.

Detailed directions for making these counts may be had from the National Canners Association, Research Laboratory, Washington, D.C.

Starch may also carry thermophiles, and if used in canning, as in cream-style corn, should be examined for its content of thermophile spores. Thermophilic spoilage is discussed further in a later section in this chapter.

Clostridium botulinum. Another very important group of spoilage bacteria are the putrefactive anaerobes. They are mesophiles; of these, *Clostridium botulinum* is the most important from the public-health standpoint because it produces a fatally poisonous toxin, and on that account all canned foods of low acidity must be processed at such times and temperatures as will destroy the maximum numbers of spores of this organism likely to be present in a canned product and having maximum resistance to heat. Much of the following information on *Cl. botulinum* is from Meyer, Dickson, Esty, and Geiger.

On the basis of type of toxin produced there are four distinct strains, A, B, C, and D. Strains A and B are of most importance to canners as they produce the most resistant spores and are the most abundant. Type A is the usual strain in the Western states, and type B in the Middle West and East. The spores of type B are usually slightly less resistant to heat then those of type A. Type C has been responsible for fatal outbreaks of botulism among wild ducks feeding in shallow water on decaying organic matter. Type D has been a cause of botulism in livestock in South Africa. The antitoxin of one strain will not protect an animal or human against the toxins of the

other strains, and it is on this basis that they are differentiated. In most other respects they resemble each other very closely.

Another peculiarity of botulism (the poisoning) is that the antitoxin must be given soon after ingestion of toxin to be effective. Public-health departments and leading bacteriological research laboratories have supplies of antitoxin.

In most media the organism produces a very characteristic penetrating butyric odor, similar to that of rancid butter. It is very pronounced in meats and peas and least noticeable in canned string beans and fruits. Cases are on record, however, in which the spoiled product (home-canned string beans) did not have a very objectionable odor.

It is found nearly everywhere in the soil. K. F. Meyer found it in many samples, including virgin soils from high peaks in the Sierra Nevada Mountains and from Yellowstone Park. It is therefore not a filth organism such as are the typhoid bacillus and *Escherichia coli* (*B. coli*). It forms one large spore per cell, giving the cell a typical drumstick appearance. The spores are surprisingly resistant to heat. Townsend and Esty state that at least 6 hr. heating at 212°F. in juices of meats and most vegetables is necessary to kill the spores of the most resistant cultures. When insufficiently heated, the spores often fail to germinate for some time in a nonacid food product. The experimental canned samples may therefore appear to be sterile, but if held long enough the spores will germinate and produce toxin. Cases are on record in which the spores have remained dormant for over a year.

Cl. botulinum produces an abundance of gas in culture media and in canned foods in which it can develop. Jars of home-canned vegetables spoiled by this organism develop heavy pressure of gas and usually become leakers. The toxin is destroyed by heating at 180°F. or the boiling point. Cases are on record in which a housewife has tasted a spoiled jar of a home-canned vegetable, decided it was edible, then cooked it and served it to the family. She developed botulism, and the other members of the family escaped, as cooking had destroyed the toxin.

Spoiled canned foods should never be tasted, and all home-canned nonacid vegetables should be boiled 10 min. or longer before serving. If that is done, any *botulinus* toxin present will be destroyed.

The toxin acts slowly; usually at least a day has elapsed before symptoms have become acute in human cases. Mortality is high; death has ensued in about 65 per cent of the human cases.

About thirty-five years ago several outbreaks of botulism occurred from underprocessed commercially canned foods, including potted meat, fish, peas, pork and beans, ripe olives, and spinach. But as a result of the universal adoption of safe processing times and of temperatures based on the research and recommendations of K. F. Meyer of the University of

California, E. C. Dickson of Stanford University, J. R. Esty, C. T. Townsend, E. J. Cameron, C. W. Bohrer, and others of the National Canners Association, as well as of those of other research agencies, there have been no cases of botulism from commercially canned foods produced in the United States in recent years. Fatal outbreaks from home-canned vegetables still occur occasionally because some home canners are not acquainted with safe methods of sterilizing. Safe commercial processing times and temperatures are given in the *National Canners Association Bulletin* 26-L.

Chickens are very susceptible to *botulinus* toxin. Many cases are on record in which spoiled home-canned vegetables have been fed to chickens, with fatal results to the fowl. In one instance more than 600 chickens were killed by home-canned string beans. In the laboratory the guinea pig is a useful test animal, because it is very sensitive to the toxin. White mice are also used. It is advisable to feed the sample rather than to inject an extract, as injection may introduce other organisms that will kill by infection. Usually both methods are employed, but with different animal specimens, of course. Injection gives much quicker results.

Forage poisoning of livestock caused by feeding ensilage or musty, moist hay containing *botulinus* toxin has occurred rather frequently. Horses are more sensitive to the toxin than are cattle.

To obtain detoxified spores for inoculation of canned and other samples, heating the culture to 180°F. for a few minutes will destroy the toxin without seriously injuring the spores.

The organism was isolated in pure culture first by Van Ermengem at Elezelles in Belgium in 1894, from ham preserved in brine that had caused the illness of 23 persons and the death of 3. He named it *Bacillus botulinus.* He proved that the bacillus is a saprophyte and that poisoning is due to a toxin. The name was changed to *Clostridium* later by other bacteriologists.

Burke of Stanford showed that the 3-day intermittent sterilization method formerly advocated for home canning of vegetables is unsafe because inoculated experimental packs heated for 1 hr. at 212°F. on each of three successive days spoiled and became very toxic. Evidently, the first or second day's heating caused the spores to become dormant instead of sprouting between heatings, and thus they survived. This method of home canning is no longer recommended.

For research on processing times and temperatures a nontoxic heat-resistant organism of the National Canners Association is often used in place of *Cl. botulinum.* It has a slightly greater heat resistance than *Cl. botulinum* and does not exhibit delayed germination.

Other Anaerobes. *Cl. sporagenes* resembles *Cl. botulinum* closely in most respects, except that it does not produce toxin. Its cells and spores resemble those of *Cl. botulinum;* it produces a butyric odor, much gas, and its spores are very resistant to heat. It has been involved in the spoilage of canned meat products and nonacid vegetables.

Cl. pasteurianum is an acid-tolerant, gas-producing anaerobe frequently responsible in the past for spoilage of canned tomatoes and tomato juice. See a later paragraph on this organism.

Other spore-bearing anaerobes have been found in spoiled canned foods. For example, Ruth Normington at the University of Michigan has described seven different strains of spore-bearing, gas-producing, heat-resistant anaerobes occurring in spoiled canned peas.

Spoilage-control Measures

Coding of Cans. Cans should be marked in some manner that makes possible quick identification of each lot or each fraction of a day's pack. Then if spoilage develops later in a certain day's pack, the particular lot concerned can be set aside and reprocessed or disposed of in some other manner. Usually such coding is done at the double seamer by a device that automatically embosses a code of letters and numbers on each lid. It usually identifies the product, its grade, the date, and the lot number.

Acidification. As mentioned in Chapter 1, the research of the author, of the National Canners Association research laboratories, and of others has shown that reducing the pH value of nonacid foods to below pH 4.5 greatly increases the killing effect of heat on heat-resistant bacteria.

Acidification of artichokes in California canneries with citric acid is now common commercial practice, making possible their safe processing at 212°F. This is done under the supervision of the State Board of Health. Kadota figs are acidified by addition of lemon concentrate to the sirup in which the figs are canned. They are then processed at 212°F. The National Canners Association has found (1955) that acidification to give a pH value of 4.9 or lower, determined after canning, is adequate to prevent danger of botulism. This corresponds to pH 4.1 to 4.2 before processing, according to one canner.

Blancher Contamination. Several years of in-plant studies by the researchers of the National Canners Association have proved that build-up of thermophiles often occurs in blanchers used for peas and string beans. Consequently, in severe cases, much thermophilic spoilage has occurred from this condition. Their data showed that in rotary-drum blanchers growth of thermophiles occurred on inner surfaces above the water line where aspirated cold air reduced temperatures to within the growth range of flat-sour bacteria. They also showed that if the temperature of these inner surfaces could be maintained at or above 160°F., contamination was greatly reduced or eliminated. The ventilating flues installed on drum blanchers allowed cold air to enter and reduce the temperature in the hood or head space of the blancher. The closing of these flues by means of dampers gave an elevation of at least 30°F. in the coldest sections of the head space and held the temperature at 170°F. or above.

In one type of blancher, it was found necessary to install hot-water sprays on the discharge mechanism, the principal beneficial effect being one washing away of scum and debris in which the thermophiles grew, in addition to maintaining a temperature above their rapid-growth range.

The principal source of contamination in the use of tubular blanchers for peas was found to be the reels into which peas are discharged after blanching to separate them from the recirculated blanch water. Use of cold chlorinated water in washing the reel and peas eliminated most of the spoilage.

Other recommendations were: Continuous injection of steam into the rotary-blancher head space (hood) was effective in maintaining temperatures above the growth range of thermophiles. The most effective single means of reducing contamination seemed to be elevation of the blanching temperature for peas to 195°F. or above. Cold-water jet sprays to wash the discharge chute outward reduced contamination at that point. Use of chlorinated water to wash blanched beans removed approximately 98 per cent of the spores on the beans leaving the blancher. A blancher that maintains safe temperatures at all points is now available (Figure 13). Other recommendations are given in the 1955 Annual Report of the National Canners Association research laboratories.

Other Factors in Spoilage Control. As Reed and Bohrer (1951) have stated, visual inspection of equipment is not reliable. Bacteriological sampling and plating are essential.

"Sanitary" equipment should mean that which is easily cleaned rather than "sterile" equipment.

Process time depends not only on the type of organism but on the numbers of its spores per can of food. If contamination is heavy, a longer process is required, a fact repeatedly demonstrated by the National Canners Association research staff.

Replace wooden brine tanks used for hot brine with metal to avoid build-up of spores in the wood.

Scale in hot brine pipes may harbor thermophiles. Remove it with dilute HCl.

In one instance thermophiles grew in juice on the canvas of a pea viner and infected the peas. The canvas had to be retorted.

Fluming canals for hot, blanched peas often grow good crops of thermophile spores. Chlorination will aid in their control; or the use of a revolving reel with sprays to cool the peas may be desirable.

Brine in the quality grader for peas may allow a build-up of thermophiles. Maintain the temperature below that for thermophile multiplication.

Can fillers for peas often grow thermophiles. They should be cleaned and flushed out frequently during the day. The principal danger is during shutdowns of an hour or more. The same is true of tomato-juice-can fillers.

The batch mixer used for cream-style corn is a favorite spot for growth of

thermophiles. Reed and Bohrer mention an instance in which an initial count of 400 spores per can grew to 40,000 per can in a short time when the temperature was allowed to drop. The mixer should be washed frequently and be brought to 180°F. or above.

As mentioned elsewhere, cooling water has frequently been a source of infection. When the hot can enters the cold water a high vacuum is formed in the head space and may draw in a minute drop of water through the heat-softened composition and infect the contents with spoilage organisms, which may or may not be thermophiles. Chlorination of the cooling water effectively controls this hazard.

Rough handling of hot cans may cause leaks, with resultant infection and spoilage.

FLAT SOURING OF CANNED FOODS

The ends of a can that has undergone flat souring appear normal; the can is not noticeably under gas pressure, but its contents are sour or at least altered in taste.

Corn. The first investigators to publish data on the flat souring of canned corn were Prescott and Underwood, who studied the souring of corn in Maine canneries. The authors spent an entire packing season in a cannery in order to study packing methods and conditions and found that cans which did not give visible evidence of spoiling were sterile and that spoiled cans contained living organisms or gave unmistakable evidence of bacterial action. They isolated pure cultures of 11 bacilli and 1 micrococcus. Of these organisms 11 formed spores, one produced gas, and all except one produced acid. Prescott and Underwood stated that flat souring of corn is more common than swelling and that the latter condition develops only under exceptional conditions. They were able to reproduce the flat souring by inoculation of sterilized cans of corn with pure cultures of most of the organisms studied. Numerous investigations have been made in recent years upon the flat souring of corn (see also section on thermophiles).

Other Vegetables. Asparagus canners in California have experienced some loss through the development of flat sours as well as gaseous spoilage, caused by thermophiles.

Spinach is packed so tightly into the cans that heat penetration is greatly retarded and sterilization is occasionally not complete; for this reason flat souring in addition to gaseous spoilage may occur.

Pumpkin, peas, and sweet potatoes occasionally undergo flat souring. Because of the poor heat conductivity of the last two products, they are difficult to cool and for this reason are particularly favorable for the growth of thermophiles. Nearly all canned vegetables are subject to flat souring, if conditions are favorable (see following section).

Spoilage by Thermophiles. Bigelow and his coworkers have demonstrated that most of the flat souring of canned vegetables, particularly of corn and pumpkin, is due to the growth of thermophilic bacteria, which develop at relatively high temperatures only, usually above 100°F. When canned vegetables are not well cooled and are allowed to stand in large stacks with the cans piled so closely together that rapid radiation of heat is prevented, the contents of the cans remain at the incubating temperature for thermophilic bacteria long enough for spoiling to occur. This condition has developed frequently in the past, but now canners realize more generally the danger of such practice, and loss from this cause is decreasing. Flat souring may also occur during shipment through the Canal Zone or storage on grocers' shelves or in other locations during very hot weather.

Bigelow and Esty (1920), Cameron (1928), and others have made extensive thermal-death-point investigations upon a number of resistant thermophilic bacteria in media of different hydrogen-ion concentrations. One thermophile, No. 26, withstood a temperature of 100°C. (212°F.) for 1,260 min. (21 hr.) and 115°C. (230°F.) for 80 min. in corn juice. A heating of 3½ hr. at 100°C. was required to destroy the spores of the least resistant of 14 other organisms reported upon, and 21 hr. at 100°C. for those of the most resistant strain. J. R. Esty stated in a lecture that one culture withstood nearly 72 hr. at 100°C. (212°F.) or 1½ hr. at 250°F.

These investigators found that the hydrogen-ion concentration of the medium exerts a marked influence on the thermal death point of thermophiles. Table 27 contains data that illustrate this effect. Of the vegetables given in the table, peas possess the lowest acidity (highest pH value) and pumpkin the highest hydrogen concentration (lowest pH value). The

TABLE 27. EFFECT OF HYDROGEN-ION CONCENTRATION ON THE THERMAL DEATH POINT OF THERMOPHILIC ORGANISMS

(Temperature 115°C., 239°F.)

Culture	Number of spores per cubic centimeter	Minutes required to destroy spores heated in:									
		Corn juice, pH 6.1		Pea juice, pH 6.3		Sweet-potato juice, pH 5.0		String bean juice, pH 5.0		Pumpkin juice, pH 4.5	
		+	−	+	−	+	−	+	−	+	−
1503	150,000	60	63	45	48	28	30	20	25	10	10.5
4109	40,000	58	60	40	45	25	28	15	18	10	11.0
1390	60,000	55	58	35	40	25	28	6	7	6	7.0
1549	50,000	35	40	25	30	15	18	10	12	5	6.0
1492	10,000	30	35	12	15	9	10	6	7	4	5.0

SOURCE: After Bigelow and Esty.

data show that the spores in most cases in pumpkin juice were killed in about one-sixth the time required for those in corn juice. This fact illustrates in a very striking manner the fallacy of specifying processing times for a given product based upon data obtained for another product of different composition.

A similar relation probably holds for most other microorganisms causing the spoiling of low-acid canned foods. It is practically impossible to sterilize foods heavily contaminated with spores of the obligate thermophiles. Control lies in preventing their entry into the product.

The obligate thermophiles are less resistant to acid than the facultative thermophiles and develop best at pH 6.0 to 8.0 and prefer starchy products such as corn. However, some of the facultative thermophiles have been encountered in canned tomatoes or tomato juice of low acidity and in very ripe pineapples. Cameron, Esty, Townsend, and their associates have given a great deal of attention to the thermophiles capable of growing in canned tomatoes and tomato juice.

In testing canned foods for the presence of thermophiles, cans of the food product may be incubated at 110 to 120°F. for about 3 weeks. If gas formers are present, the cans will swell. If facultative flat-sour thermophiles are present, the pH value will drop to 4.8 or even lower. The liquid may be tested with bromocresol green in such cases. If obligate thermophiles of the flat-sour type are present, the pH value will usually drop to about 5.2, the juice or brine being tested with bromocresol purple. The glass electrode may be used for more accurate determination of pH value.

In an extensive survey of thermophilic spoilage in canneries in the Middle West, Cameron and associates of the National Canners Association found that the usual sources of contamination were tanks of hot water or hot brine, or other equipment maintained at a temperature high enough for growth of thermophiles. The wood of wooden tanks used for blanching water or hot brine in some cases became heavily seeded with thermophile spores. The raw products, corn and peas, carried very few thermophilic spores. However, it has been found in California that asparagus may carry considerable numbers of resistant spores from the soil. In respect to flat souring and sulfide spoilage (H_2S-forming thermophiles) of corn and peas, Cameron recommends that wooden tanks for blanching or for preparation of hot brine or water be replaced with resistant metal or glass-lined metal tanks and that the hot liquids be not carried over from day to day but be made fresh each day. Liquids must not be allowed to stand warm in pipelines, pumps, etc., between shutdowns, as spores may be formed in enormous numbers. Such equipment should be flushed out thoroughly before beginning the day's operations.

Sugar may be a source of thermophilic spores, since in sugar manufacture opportunity exists in some stages of the operations for growth and sporula-

tion of thermophiles. Some of the spores may carry through into the finished product. Sugar for use in corn and pea canning is now bought on the basis of its content of thermophile spores. The National Canners Association has specified the method of estimating the number of such spores and their type, e.g., flat sours, hydrogen sulfide formers, and gas formers. See the earlier section in this chapter for National Canners Association recommended tolerances for spore content of sugar.

SPOILAGE BY ACID-TOLERANT FLAT-SOUR ORGANISMS

Tanner states that Pearce and Ruyle in 1938 found that Indiana tomato juice is occasionally spoiled by a flat-sour, heat-resistant, mildly thermophilic bacillus, known as *Bacillus thermoacidurans* of Berry.

An off flavor is developed in tomato juice without formation of gas; i.e., the can does not swell, thus differing from spoilage by *Clostridium pasteurianum.* The organism does not grow in all tomato juices even when they are underprocessed and appears to prefer Eastern and Middle Western juices to Western. It is believed that build-up of the spores in equipment in the plant is the chief source of contamination. Frequent clean-up and avoiding the standing of juice or wash water in pipes, pumps, etc., is indicated.

As stated elsewhere, Cameron recommends that tomato juice in No. 1 cans be processed not less than 15 min. at 212°F., No. 2½ not less than 20 min., No. 2 not less than 25 min., and No. 10 not less than 40 min., with an initial temperature of 170 to 180°F. He also recommends taking and incubating of daily samples. Growth is quite rapid at 98 to 100°F. However, most canneries sterilize the juice by flash pasteurization at about 250°F., cooling to about 210°F., canning at 205 to 210°F., holding for several minutes to sterilize can ends, and final cooling. Examination of the cut samples for flat souring is made after each incubation. pH value usually drops during spoilage, and an easily recognizable off flavor and odor develop. Cultures can be made in proteose peptone acid–agar medium by way of check.

NONPOISONOUS GASEOUS SPOILING

Gaseous decomposition occurs with all canned foods under favorable conditions. Gaseous spoilage may be classified as nonpoisonous or poisonous.

Fruits. Examination of swelled cans of fruit usually reveals the presence of yeast cells and evidence of alcoholic fermentation. Yeasts are very rapid producers of carbon dioxide, which accounts for the frequent bursting of spoiled cans of fruit. Occasionally bacteria have been proved to be the cause of spoiling of canned fruits, particularly very ripe pineapple, figs,

and pears and less frequently Pie-grade peaches, all being fruits of low acidity.

Spoiling of canned fruit by yeast usually signifies leaky cans or gross carelessness in sterilization. An exception to this statement is the spoiling of solid-pack Pie fruit, in which heat penetration is so slow that the centers of No. 10 cans may not reach a temperature fatal to yeasts, if the sterilizing process used for sirup-packed fruits is applied. Also, with over-ripe Pie fruit the pH value may be so high as to permit growth of spore-bearing bacteria.

Vegetables. The first important bacteriological investigation of swelled canned vegetables was conducted by H. L. Russell at the University of Wisconsin in 1895, at a time when the canners of Wisconsin were losing large quantities of canned peas. They knew very little about bacteria and placed the blame for the spoiling upon various factors later proved to have little or no relation to the problem. From swelled cans of peas Russell isolated two species of bacteria, of which one produced typical swells when inoculated into sterile cans of peas. He recommended the increase of the processing temperature from 232 to 242°F. and the time from 26 to 28 min. Previous to the adoption of this recommendation, the number of swells had been about 5 per cent of the total pack; after its adoption, this type of spoiling was reduced to a negligible amount.

Prescott and Underwood at the Massachusetts Institute of Technology in 1896 and 1897 made important contributions to the knowledge of the swelling of canned corn. Their investigations, while more extensive than those of Russell, yielded similar results. Other canned vegetables, notably spinach, undergo gaseous spoiling if not well sterilized.

Because of the low oxygen content of canned foods, spoiling is usually caused by anaerobes or facultative anaerobes. Of the spore-bearing gas formers, other than thermophiles, *Bacillus sporogenes* is among those most commonly found in swelled cans of vegetables. Organisms of the *B. coli* group frequently cause gas formation in leaky cans, but because they do not form spores, they very rarely survive processing.

The heat-resistant organisms occurring on peas were studied extensively at the Michigan Experiment Station by Ruth Normington, who described seven strains of spore-bearing, heat-resistant, gas-producing bacteria.

As previously stated, certain obligate thermophiles produce CO_2 and H_2 in canned foods at low acidity. They are anaerobic and very resistant to heat.

ANAEROBIC SPOILAGE OF ACID FOODS

Townsend (1938) described the spoilage of several kinds of canned fruits and vegetables, but particularly tomatoes, by anaerobic, spore-bearing, acid-tolerant bacteria that he identified as *Clostridium pasteurianum*, or

very closely related to this organism. He reported on six strains isolated from tomatoes, pears, and figs, all canned in the usual commercial manner.

He found that the soil from which these products came was heavily contaminated with the spores of the spoilage organisms.

In suitable media the bacteria grew readily at pH values of 4.0 or above and slowly at pH values of 3.6 to 4.0. Therefore the problem of control is a difficult one. Townsend suggests that the sirup or brine in which the products are canned might be acidified, thereby lowering the death temperature and time of the spores. It required twice as long to kill the spores at pH 4.5 as at pH 4.1 and nearly five times as long as at pH 3.8. At pH 4.5 the most resistant strain survived 15 min. at 212°F. but was killed at 20 min. At pH 4.1 maximum survival time was between 9 and 12 min., with destruction at 12 min. At lower pH values the death times were of briefer duration.

Spiegelberg in Honolulu (1939) reported spoilage of canned pineapple by a similar organism, identical with or very closely related to *C. pasteurianum* of Winogradsky. Thus it is well established that this organism can grow in and spoil, with gas fermentation and development of a butyric odor, such acid foods as canned tomatoes, pineapple, and pears.

Spoilage of Hot-filled Products. Many acid products such as fruit juices, fruit nectars, jellies, tomato juice, tomato purée, and tomato paste are presterilized in a continuous tubular or plate type or other sterilizer, filled hot into cans previously washed in hot water or blown out with steam, sealed at once, held several minutes to sterilize can body and ends, and then cooled in the usual manner. Spoilage has occurred in such products. Collier and Townsend (1954), who have made a detailed study of this method of canning and of the spoilage, state that lactobacilli and yeasts have been the principal microorganisms responsible for the spoilage in such cases. Yeasts cause rapid fermentation in the product with swelling and bursting of the cans, usually within a week after canning, whereas the lactic bacteria grow much more slowly. A month or longer may be required after canning for lactic-bacterial spoilage to result in even a mild swell or springer.

The products are usually filled at 195°F. or above, and the filled cans travel for from 3 to 15 sec. between the filling machine and the can double-seamer. The sealed cans are then held for several minutes, usually on a slowly moving belt or other conveyer. They may or may not be washed immediately after sealing.

Collier and Townsend make the following recommendations to reduce spoilage to a minimum:

1. The filling temperature of the product as it goes into the cans must be 200°F. or above, except as outlined in recommendations 5 and 6.

2. Preferably no washing of the cans immediately after sealing; but if it is done use water of at least 160°F.

3. The cans should be rolled, rocked, or inverted during part of the holding period so that agitation of the contents will occur and excess water, if any, will be drained off the cans, since its evaporation from the can surface has a cooling effect on contents.

4. Do not place the cans on wet rubber belts or solid metal plates or expose them to strong, cool air currents.

5. For highly viscous products such as tomato paste and fruit concentrates, use one of the following methods. Fill at 195°F. or above, wash with water at or above 160°F., and sterilize at 180°F. or higher for a minimum of 2 min., then cool. Or fill at 200°F. or above, wash with water at or above 160°F., and roll cans to remove excess water. Hold the cans for at least 5 min., if in an enclosed space, or at least 8 min. in the open. Water-cool. The third procedure is the same as in the second method in this paragraph except that the cans after washing and rolling are placed on wooden trays to cool in the air.

6. All these products, both juices and more concentrated products, packed in small cans, smaller than 211 × 414 for tomato and fruit juices and smaller than 303 × 406 for tomato paste and fruit concentrates, filled at 190°F. or above, should receive a processing of at least 2 min. at 195°F. or above, or an equivalent process, until further data are obtained for these containers.

Tomato paste in 6-oz. cans has been one of the principal products concerned in spoilage of hot-filled liquid or semiliquid products. Canners now process these cans of paste for at least 2 min. in a continuous processor, usually heated by live steam.

SPOILAGE BY BYSSOCHLAMYS FULVA AND OTHER MOLDS

A costly form of spoilage of canned fruits caused by a heat-resistant mold has appeared in England. The organism withstands 86 to 88°C. for 30 min. in some fruit sirups. It has been particularly destructive in canned plums and berries. The contents of the can is partially liquefied by the organism. It has been named *Byssochlamys fulva* and has been described by Olliver and Rendle (see reference in the bibliography at the end of this chapter).

Occasionally jellies, jams, and bottled juices are spoiled by *Penicillium* molds whose spores have survived pasteurization. Most are killed at or below 180°F. Canned blueberries in Maine have been spoiled occasionally by a heat-resistant mold.

LIVING ORGANISMS IN SOUND CANNED FOODS

It is often assumed that canned foods which do not undergo visible spoiling are sterile, but investigations have proved that this assumption is not correct in many cases.

Meats. Weinzirl states that in 1900 Vaillard in France examined bacteriologically a large number of samples of canned meats, many of which were edible and to outward appearance sterile, and found living bacteria in 70 to 80 per cent of them.

Sadler found that normal cans of fish frequently contain living organisms. Hunter and Thom found 224 out of 530 cans of commercially packed salmon to contain living spores of a resistant bacillus. There was no evidence of spoiling in any of these samples.

Weinzirl at Harvard examined a large number of samples of canned meats, including sardines, and found that 19.5 per cent of 273 apparently sound commercial samples contained living organisms. Most of the organisms were spore-bearing aerobes. Canned oysters, clams, salmon, and soups were found sterile in most cases.

Milk. Sweetened condensed milk was found by Weinzirl to contain *Bacillus mesentericus* and *B. subtilis*. This product is not sterilized at a high temperature. Evaporated unsweetened milk was sterile in most cases, because it is given a severe sterilization under pressure.

Fruits. Most fruits are processed at 100°C. (212°F.) for a short period only. Therefore it might be expected that spore bearers would survive and be found in commercially canned fruits.

In the examination of 104 cans of normal appearance, Weinzirl found living mold spores in 4 cans and spore-bearing bacteria in 31 cans. *B. subtilis* occurred 14 times, *B. mesentericus* 10 times, *B. cereus* 8 times, *B. vulgatus* 3 times, and thermophiles 9 times. Yeasts were not found. The fruit in all cases was normal in appearance and showed no evidence of bacterial growth.

Beresford at the University of California found viable spore-bearing bacteria in olives processed at 202 to 230°F. but none in olives sterilized at 240 to 250°F. for 20 to 30 min. Nolte and von Loesecke (1940) isolated living organisms from canned citrus juices, but none were able to grow in the juices because of their low pH value.

Vegetables. Weinzirl reports results from the examination of commercially canned vegetables very similar to those given above for fruits. No yeasts were encountered in 370 samples of commercially canned vegetables of normal appearance. Molds occurred in 2 per cent of the cans, and spore-bearing bacteria in 20.5 per cent. Much the same types of bacteria were found as listed above for fruits.

Incubation at 37°C. did not cause these organisms to develop in the unopened cans, probably because of lack of oxygen. The bacteria were found to develop readily in the vegetables under aerobic conditions. Apparently the absence of oxygen is the principal limiting factor, although Bigelow, Esty, and others have shown conclusively that canned vegetables containing living thermophiles will keep perfectly unless stored at temperatures

above 100°F. Michael and Tanner (1936) examined 900 cans of cream-style corn and found 24 per cent nonsterile, most of the organisms being facultative thermophiles. Such cans of corn would usually spoil when incubated at elevated temperatures.

LABORATORY EXAMINATION OF SPOILED CANNED FOODS

While it is not the function of this text to present full directions for the laboratory examination of food products, a very brief summary of recommended procedure for examining spoiled canned foods is probably justified. For details the reader is referred to the *Journal of Official Agricultural Chemists*, 1936, pp. 428–449.

Treatment of Unopened Container. The top of the can should be sterilized. If the can is a swell, it must not be heated, as heating may cause it to burst. Such cans should first be scrubbed with soap and water if dirty. The top may then be sterilized with 1:1,000 mercury bichloride. If the can shows no pressure, the top may be flamed with a Bunsen burner, or a few cubic centimeters of alcohol may be placed on the top and burned off.

Fellers recommends that a hole about 1½ in. in diameter be cut in the top with a flame-sterilized awl or a sterilized cheap can opener. The can is covered with a sterile Petri-dish cover if not sampled at once.

If the can is a hydrogen swell, it should be examined for perforations.

Liquid samples may be taken by pipette with wide opening. Solid samples may be taken with a large sterile cork borer or sterile piece of glass tubing. Tanner recommends samples be taken well below the surface of the contents.

The culture medium will vary according to the nature of the spoilage organisms, although Cameron states that there is much less need for special media than many bacteriologists believe. He recommends tryptone agar for flat-sour organisms. It consists of tryptone, dextrose, agar, and water containing a small amount of bromocresol purple. Incubation is at 55°C. Flat-sour colonies show a yellow halo.

He states that liver broth reinforced with peptone and dipotassium phosphate is satisfactory for anaerobic bacteria, either mesophiles or thermophiles. The medium is heated before inoculation to expel oxygen and is stratified with sterile petroleum jelly or sterile plain agar after inoculation. Incubation is at 55°C. for thermophiles and 37°C. for mesophiles. The agar is split by gas formation if viable anaerobes are present. He recommends for trial also a medium made of 2 per cent dry liver and 5 per cent corn meal. It is autoclaved at 15 to 17 lb. steam pressure. Growth is evidenced by gas formation, as the medium is very thick in consistency.

In order to test for the presence of hydrogen sulfide-forming *C nigri-*

ficans, a yeast-water agar containing 0.1 per cent sodium sulfite and 3 per cent sucrose is used. In each tube is placed a small, clean iron strip.

James finds that tomato-juice broth agar is satisfactory for many organisms from spoiled acid foods. He also uses malt-extract tomato-juice agar. For lactic acid bacteria Vaughn of the University of California finds diluted, filtered tomato juice an excellent medium. For molds and yeasts there are no better media than grape juice diluted one-half with water or filtered, undiluted orange juice. These juices are easily sterilized at 100°C.

Dunbar recommends incubating tubes for thermophiles at 52 to 55°C. instead of the 45°C. used by some, because at 45°C. some mesophiles may grow. He points out also that if the medium is incubated at 37 to 38°C., there is very rapid growth of blood-temperature organisms, which may crowd out bacteria that develop best at lower temperatures. Therefore he recommends an incubation at 30 to 32°C. for mesophiles.

Occasionally, although the can is swelled and microscopical examination shows enormous numbers of bacteria, growth in culture media is negative because the products of metabolism have killed the organisms.

For testing the toxicity of spoiled canned foods for *botulinus* toxin, small amounts of the contents are fed to guinea pigs or to white mice or to both. Typical symptoms develop, usually within 24 hr., and death ensues if much toxin is present.

FOOD POISONING OTHER THAN BOTULISM

Canned foods spoiled in the can by organisms other than *Cl. botulinum* are usually not toxic. However, after the can has been opened, the food may be set away for several days at room temperature or used in a salad or other mixed dish. If these canned foods should become infected with certain organisms and stand long enough, they may become toxic or they may contain paratyphoid bacteria or other infectious organisms. In other words, after the food is taken from the can it can become infected just as can any other food; and if it is a nonacid food such as fish, meat, or nonacid vegetables, it can become toxic or infectious.

Jordan (1931) has summarized the whole subject of food poisoning very well in a small book (see bibliography). He points out that many outbreaks of food poisoning, usually termed erroneously "ptomaine poisoning," are caused by a toxin formed by *Staphylococcus* in such foods as cream puffs, cream pies, stews, creamed meat and fish dishes, and so on. He states that in the cases examined in his laboratory *Staphylococcus aureus* and *Staph. albus* were responsible for the toxin formation. He found the toxin somewhat resistant to heat, withstanding a few minutes but not prolonged boiling. He found no outbreaks due to toxin formation by organisms of the Salmonella group (paratyphoid, etc.). However, other workers have en-

countered outbreaks of serious infection by members of the Salmonella group such as *Salmonella aertrycke* and *S. enteritiditis*, i.e., intestinal bacterial infections. In these outbreaks the organisms set up a general paratyphoid-type infection that runs a violent course that is usually not fatal. According to Jordan, so-called "rat virus," a Salmonella preparation at one time used for exterminating rats by disease, has gotten into food and caused paratyphoid-type cases, some of which were fatal.

Tanner (1944) has also covered the subject of food-borne infections and poisonings quite thoroughly. For further discussion of the subject the reader is referred to his and Jordan's books.

REFERENCES

Baker, H. A.: Springers in canned foods, *Proc. Intern. Cong. Appl. Chem., 8th Cong.*, **18**, 30–43, 1912.

Bengsten, I. A.: Studies of organisms in botulism, *U.S. Public Health Serv. Bull.* 136, 1924.

Bigelow, W. D.: Springers and perforations in canned foods, *Natl. Canners Assoc., Research Lab., Circ.* 1-L, 1922.

———: Tin in canned foods, *J. Ind. Eng. Chem.*, **8**, 813, 1916.

——— and Esty, J. R.: The thermal death point in relation to time of typical thermophilic organisms, *J. Bacteriol.*, **27**, 602–617, 1920.

——— and Miller, H. M.: A cause of dark color in canned corn, *Natl. Canners Assoc., Research Lab., Bull.* 6, 1915.

Blumenshine, F. L.: Boiler operation to control water carryover, *Proc. Tech. Sess. 47th Ann. Conv. Natl. Canners Assoc.* Jan. 23–27, 1954, pp. 11–13.

Bohart, G. S.: Special enamel for corn cans, *Natl. Canners Assoc., Research Lab., Circ.* 10-L, 1924.

Bohrer, C. W.: Some spoilage prevention aspects of washing and quality grading operations, *Natl. Canners Assoc. Inform. Letter* 1526, pp. 9–11, Feb. 28, 1955.

Burke, Georgina S.: The effect of heat on the spores of Bacillus botulinus, *J. Am. Med. Assoc.*, **72**, 88–92, 1919.

Cameron, E. J., and Esty, J. R.: Comments on the microbiology of spoilage in canned foods, *Food Research*, **5**(6), 549–557, November–December, 1940.

———, Williams, C. C., and Thompson, R. J.: Bacteriological field studies in canning, *Natl. Canners Assoc., Research Lab., Bull.* 25-L, 1928.

Cheftel, H.: La corrosion du fer blanc, *Etablissements J.-J. Carnaud et forges Basse-Indre, Lab. recherches, Bull.* 5, 1935.

Clark, F. M., and Tanner, F. W.: Thermophilic canned food spoilage organisms in sugar and starch, *Food Research*, **2**(1), 27–40, 1937.

Clough, R. W., Shostrom, O. E., and Clark, E. D.: Lime sulfur in canned gooseberries, *Canning Age*, **5**, 531, 1924. Effect on corrosion by canned product.

Collier, C. P., and Townsend, C. T.: Container sterilization for acid products by hot-fill-hold-cool procedures, *Proc. Tech. Sess. 47th Ann. Conv. Natl. Canners Assoc.*, Jan. 23–27, 1954, pp. 28–36.

Cruess, W. V.: Production snags, *Canner*, **115**, 11–22, Mar. 22, 1952; 18–22, Mar. 29, 1952.

———, Fong, W. Y., and Liu, T. C.: The role of acidity in vegetable canning, *Univ. Calif. Expt. Sta., Hilgardia Paper*, vol. 1, no. 13, 1925.

CULPEPPER, C. W., and CALDWELL, J. S.: The behavior of anthocyanin pigments in canning, *J. Agr. Research*, **35**, 127, 1927.

——— and MOON, H. H.: The corrosive action of organic acids upon the tin can, *Canner*, **68**(9), 13, 1929.

DEBORD, M. S., EDMONSON, R. B., and THOM, C. C.: Summary of Bureau of Chemistry investigations on botulism, *J. Am. Med. Assoc.*, **74**, 122–222, 1920.

DICKSON, E. C.: Botulism, *Rockefeller Inst. Monograph* 8, 1918.

ESTY, J. R., and CAMERON, E. J.: The examination of spoiled canned foods. 2. Flat sour organisms, *J. Infectious Diseases*, **39**, 89–105, 1926.

——— and MEYER, K. F.: The heat resistance of spores of Bacillus botulinus and allied anaerobes, *J. Infectious Diseases*, **31**, 650–663, 1922.

FARKAS, D. F., GOLDBLITH, S. A., and PROCTOR, B. E.: Stopping storage off flavors by curbing peroxidase, *Food Eng.*, **28**(1), 52, 53, 152, January, 1956.

Flat sour spoilage of tomato juice, *Continental Can Co., Research Dept., Bull.* 16, 1948.

GEIGER, J. C., MEYER, K. F., and DICKSON, E. C.: Epidemiology of botulism, *U.S. Public Health Serv. Bull.* 127, 1922.

GILLESPY, T. G.: The heat resistance of the spores of thermophilic bacteria, *Ann. Rept. Fruit Vegetable Preserv. Research Sta., Campden, England*, 1948, p. 40.

GUYER, R. B., and HOLMQUIST, J. W.: Enzyme regeneration in high-temperature-short-time sterilized canned foods, *Continental Can Co., Research Dept., Bull.*, 1955.

HALL, I. C.: New outbreaks in botulism in Western United States, *Food Research*, **1**, 171, 1936. Also *J. Am. Med. Assoc.*, **108**, 1961–1964, 1937. Mushrooms.

HIRST, F. W., and ADAM, W. B.: Springers, hydrogen swells and perforations in canned fruits, *Univ. Bristol, Canning Research Sta., Canners' Bull.* 1, 1930.

HOBMAEIR, M.: Botulism in duck disease, *Calif. Fish and Game Bull.*, **18**(1), January, 1932.

JONES, O., and JONES, T. W.: "Canning practice and Control," Chemical Publishing Company, Inc., New York, 1937.

JORDAN, E. O.: "Food Poisoning," 2d ed., University of Chicago Press, Chicago, 1931.

KOHMAN, E. F.: Corrosion of enameled tin plated covers on glass containers, *Canner*, **113**, 16–20, 26, Sept. 2, 1950.

——— and SANBORN, N. H.: Tin plate and the electrochemical series, *Ind. Eng. Chem.*, **20**(76), 1373, 1928; **22**, 615, 1930.

LUECK, R. H., and BLAIR, H. T.: Corrosion in the tin can, *Trans. Am. Electrochem. Soc.*, **54**, 257, 1928.

MEYER, K. F., DUBOVSKY, J., ET AL.: The distribution of spores of Bacillus botulinus, *J. Infectious Diseases*, **31**, 501–616. Also *Monthly Bull. Calif. State Board Health*, September, 1920, pp. 38–43.

MICHAEL, VIOLA M., and TANNER, F. W.: Microbiology of merchantable cream-style canned corn, *Food Research*, **1**(1), 99–112, 1936.

MORRIS, T. N., and BRYAN, J. M.: The corrosion of the tin plate container by food products, *Dept. Sci. Ind. Research (Brit.), Food Invest., Spec. Rept.* 40, 1931.

MRAK, E. M., and RICHERT, P. H.: Swelling of canned prunes, *Univ. Calif. Agr. Expt. Sta. Bull.* 508, 1931.

MUDRA, A. E., and ROYCE, R.: Effect on containers of boiler water carryover, *Proc. Tech. Sess. 47th Ann. Conv. Natl. Canners Assoc.*, Jan. 23–27, 1954, pp. 6–9.

National Canners Association, Research Laboratories: Annual Reports, 1950–1956. Sections on bacteriological studies and spoilage.

NOLTE, A. J., and VON LOESECKE, H. W.: Types of organisms surviving in commercially pasteurized citrus juices in Florida, *Food Research*, **5**(1), 73–81, January–February, 1940.

Olliver, M., and Rendle, T.: A new problem in fruit preservation, Byssochlamys fulva, *J. Soc. Chem. Ind. (London)*, **53**(22), 166T–172T, 1934.

Processes for nonacid canned foods, *Natl. Canners Assoc., Research Lab., Bull.* 26-L, 1956.

Reed, J. M., and Bohrer, C. W.: Engineering factors relating to spoilage control in canning factories, *Canner*, Apr. 28, 1951, pp. 8–12.

———, ———, and Cameron, E. J.: Spore destruction rate studies on organisms of significance in the processing of canned foods, *Food Research*, **16**(5), 383–408, 1951.

Schafer, C. J.: Boiler water treatment methods to avoid carryover, *Proc. Tech. Sess. 47th Ann. Conv. Natl. Canners Assoc.* Jan. 23–27, 1954, pp. 9–11.

Schoenholz, P., and Meyer, K. F.: Studies on the serologic classification of B. botulinus, *J. Immunol.*, **1**(1), 1925.

———, Esty, J. R., and Meyer, K. F.: Toxin production and signs of spoilage in commercially canned vegetables and fruits inoculated with detoxified spores of B. botulinus, *J. Infectious Diseases*, **33**, 289–327, 1923.

Scott, W. J.: Thermal destruction of Type A Cl. botulinum toxin, *Australian J. Appl. Sci.*, **1**(2), 200–207, 1950.

Smith, C. L.: The relationship of spoilage to rough handling and contaminated cooling water, *Continental Can Co., Research Dept., Bull.* 9, 1946.

Sognefest, P., Hays, G. L., Wheaton, E., and Benjamin, H. R.: Effect of pH on thermal process requirements for canned foods, *Food Research*, **13**, 400–410, 1948.

Speller, F. N.: "Corrosion, Causes and Prevention," McGraw-Hill Book Company, Inc., New York, 1928.

Spiegelberg, C. H.: Clostridium pasteurianum associated with spoilage of acid canned fruit, *Food Research*, **5**(2), 115–131, March–April, 1940.

Stumbo, C. R.: Bacteriological considerations relating to process evaluation, *Food Technol.*, **2**, 115, 1948.

Tanner, F. W.: "Microbiology of Foods," 2d ed., Garrard Press, Champaign, Ill., 1944.

Townsend, C. T.: Spore bearing anaerobes causing spoilage in canned foods, *Food Research*, **4**(3), 231–238, 1939.

——— and Collier, C. P.: Establishing sterilization procedures for aseptic canning units, *Natl. Canners Assoc. Inform. Letter* 1526, Feb. 28, 1955.

——— and Esty, J. R.: Micro-organisms in canning, *Western Canner and Packer*, June, July, and August, 1939.

———, ———, and Baselt, F. C.: Heat resistance studies on spores of putrefactive anaerobes in relation to determination of safe processes for canned foods, *Food Research*, **3**(3), 323–347, May–June, 1938.

———, Yee, L., and Mercer, W. A.: Inhibition of the growth of Clostridium botulinum by acidification, *Food Research*, **19**(5), 536–542, 1954.

Tracy, R. T.: Spoilage of olives by colon bacilli, *J. Bacteriol.*, **28**, 249–265, 1934.

Van Ermengem, E.: Contribution a l'étude des intoxications alimentaires, *Arch. pharmacol.*, **3**, 213, 1897.

Vaughn, R. H.: The pectolytic activity of the genus Bacillus and their relation to the softening of olives and pickles, *Proc. Calif. Olive Assoc. Tech. Conf.*, 1952, pp. 67–69.

Weinzirl, J.: The bacteriology of canned foods, *J. Med. Research*, **39**, 349–413, 1919.

Williams, O. B., and Cameron, E. J.: Molding of canned blueberries, *Food Research*, **6**(1), 69–73, 1941.

Wyant, Z. N., and Normington, R.: Resistance of spores of Bacillus botulinus to salt, *J. Bacteriol.*, **5**(6), 553–557, 1920.

CHAPTER 12

UNFERMENTED FRUIT BEVERAGES[1]

Annual Production. The production of fruit juices has increased greatly in recent years owing to the phenomenal increase in the canning of various juices since 1929, in which year tomato juice was first canned in important amount. It is estimated that approximately 75 million cases of canned fruit juices other than tomato are now (1957) produced annually in the United States.

In Table 28 are given data on the annual United States production of canned and bottled fruit juices.

TABLE 28. TOTAL UNITED STATES PRODUCTION OF CANNED AND BOTTLED FRUIT JUICES
(In cases of 24 qt.)

Year	Apple juice, bottled and canned	Grape juice, bottled	Grapefruit juice, canned	Orange juice, canned	Pineapple juice, canned	Tomato juice, canned
1929	No data	1,000,000*	205,000	....	....	185,000
1930	No data	1,000,000*	179,934	37,552	....	1,338,964
1932	No data	1,000,000*	288,324	36,362	....	4,583,635
1933	No data	1,000,000*	728,691	110,597	700,000	4,170,794
1935	1,250,000	1,000,000	2,675,586	1,107,299	2,500,000	8,170,640
1936	1,450,000	1,000,000	2,227,074	1,462,452	5,000,000	13,104,809
1941	1,726,000	3,000,000	16,759,000	3,884,000	11,280,000	19,046,000
1942	1,900,000	2,300,000	13,000,000	4,906,000	8,700,000	20,738,000
1945	1,500,000	1,500,000	20,548,000	18,424,000	7,953,000	28,389,000
1950	3,470,060	3,000,000	16,285,000	20,870,000	12,354,000	22,741,000
1956	4,266,000	7,200,000	13,000,000	18,000,000	14,500,000	38,017,000

* Approximation.
SOURCE: *Western Canner and Packer*, May, 1955.

In addition to those listed in the table, other juices are canned commercially in moderate quantities for which production data are not readily available. The most important are canned loganberry, apricot,

[1] The author is greatly indebted to M. A. Joslyn and G. L. Marsh for use of much of the information presented in their Production of fruit juices, *Univ. California Agr. Expt. Sta. Circ.* 344, 1937.

blackberry, cranberry, and prune juices. Canned prune juice has proved particularly popular, and its production should increase. Apple juice is now canned commercially. Apricot and other nectars are sweetened, diluted purées.

The *Western Canner and Packer* gives the following statistics for 1955: fruit nectars, 4,500,000 cases; lemon and lime juices, 1,400,000; orange and grapefruit blend, 4,500,000; miscellaneous, including berry juices, 200,000; and vegetable juices other than tomato, 300,000. Prune juice was estimated at 7,500,000 cases for 1955.

In addition to bottled and canned fruit juices a large quantity of orange juice is consumed fresh at juice stands and in the home. Large amounts of orange concentrate and of orange sirup are used as a base for carbonated bottled beverages and for a bottled noncarbonated beverage; in both cases the sirup or concentrate is diluted greatly with water before bottling, and the products are preserved with sodium benzoate. During the Second World War a great deal of orange concentrate was exported to Great Britain to be used by children as a source of vitamin C. Very large amounts of citrus and other fruit concentrates are preserved by freezing (Chapter 25).

Various carbonated bottled drinks (soda water) are consumed in great quantities in the United States. While some of these bear "fruity" names, usually they contain little to no fruit juice. The author has long believed that there is a great opportunity for improving these beverages and for providing an important outlet for fruits by including an appreciable amount of fruit in those beverages which carry fruit labels, such as strawberry, raspberry, grape, lemon, orange, and lime.[1]

Formerly it was customary to clarify fruit juices either by filtration or by fining before bottling. At present most of the preserved juices on the market are cloudy or pulpy or clarified with a pectic enzyme.

GENERAL METHODS AND EQUIPMENT

Fruit juices are most palatable when first expressed from the fresh fruit, and any treatment applied to preserve or clarify them results in more or less injury to quality. Preservation must be accomplished with as little injury as possible to the fresh flavor and other desirable qualities of the product.

Choice of Fruit. Fruit that is to be used for the preparation of juice should be of marked and agreeable flavor and aroma, must have "character," should not be flat or insipid in flavor, and should be of tart flavor,

[1] See *Univ. California, Coll. Agr. Bull.* 359 (1923), *Circ.* 313 (1932), and *Circ.* 349 (1941), for further discussion of this suggestion.

i.e., moderately rich in acid. In addition the juice should retain its character satisfactorily during processing and during storage after bottling or canning.

Harvesting and Transportation of the Fruit. Fruit juices must be prepared from sound fruit only. Even slight fermentation or mold growth that would not seriously injure some fruits for other purposes will spoil the flavor of the juice for beverage purposes. This fact makes it necessary also to use only clean boxes, free from mold, in picking and transporting the fruit to the factory.

The fruit should be picked at the proper stage of maturity for the preparation of juice, which will vary with the variety. Thus loganberries should be picked when they have become "dead" ripe, i.e., soft ripe, for they are then at their optimum color and flavor. Vinifera grapes, with the exception of the Muscat variety, should be picked when slightly underripe, in order that the juice may not be too low in acidity and too rich in sugar. For the same reason apples should not be allowed to become overripe and mealy in texture before crushing.

Importance of Sorting and Washing. Sorting is usually desirable and frequently necessary before the fruit is crushed and can be accomplished in the same manner as described elsewhere for tomatoes.

Most fruits accumulate some dust in the field or during transportation. For this reason they should be rinsed thoroughly by sprays of water before crushing. Fruit that has become contaminated by moldy fruit, as is sometimes the case with apples stored in bins, requires vigorous washing. Oranges in some sections develop a sooty mold deposit on the surface, which can only be removed by scrubbing and washing.

Berries and other soft fruits can be washed satisfactorily as they pass beneath water sprays on a woven-metal conveyer.

Choice of Metal. The crusher should be of such material that it does not react with the juice. Iron or steel rolls or knives are liable to cause darkening of some juices by the solution of a small amount of iron, which reacts with the tannin and coloring matter of the juice to produce a black or dark brown color.

Stainless steel is extremely resistant to the action of fruit juices and should be used for crushers, reamers, pipes, bulk pasteurizers, and other equipment if the volume of output warrants the expense. Aluminum bronze is satisfactory for filter frames. Tin-copper bronze free of zinc is usually satisfactory for cocks and pipe couplings. Nickel and monel metal are satisfactory for some juices. Copper and tin are objectionable because even small concentrations of their salts adversely affect the flavor and color of most juices and catalyze undesirable changes. Iron and steel are very undesirable.

Grape crushers should be made of resistant bronze or other alloy or

metal not attacked by the juice. For further discussion see papers of Mrak and Leroux and of Mrak and Cruess on corrosion.

Preparing Fruit for Juice Extraction. The extraction of juice from fruit usually involves crushing and pressing, although there are exceptions, notably with apricots, peaches, and citrus fruits.

The method of extraction depends upon the structure of the fruit, location and character of the tissues in which the juice is located, and

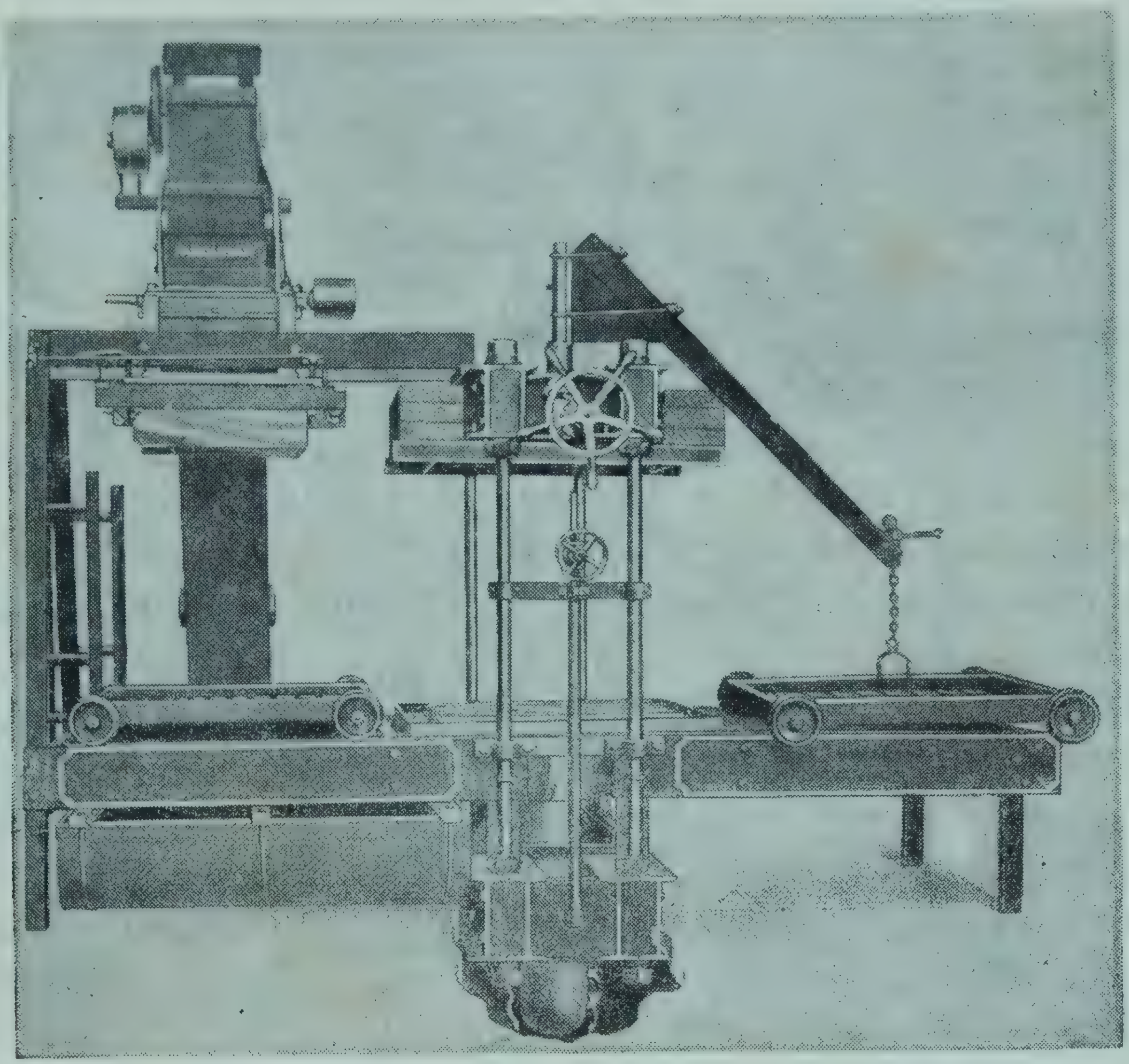


Fig. 59. Large fruit crusher and hydraulic press. (*A. B. Farquhar Div., Oliver Corp., York, Pa.*)

the character of the finished juice. In some fruits, as in apples and grapes, the juice is located throughout the fruit and is readily recovered by crushing and pressing. In others, as in citrus fruits and pomegranates, the juice-containing tissue is surrounded by a thick skin that contains soluble substances of objectionable flavor or color; therefore the juices of such fruits must be extracted in such manner as to avoid extracting the undesirable substances from the skins.

From apricots, peaches, and tomatoes pulpy juices are prepared; consequently, the raw or the cooked fruits are passed through some sort of pulper to give a purée like liquid containing a large proportion of suspended, finely divided solids.

Undue aeration must be avoided during the extraction of juices from fruits that have not been heated to destroy enzymes, since destruction of

vitamin C and oxidative changes in flavor are very rapid in some juices, particularly apples and tomato juices. These changes are catalyzed by traces of iron and copper in solution.

Crushers are of various types. That generally used for grapes consists of two fluted-metal rollers which revolve toward each other. They are set at such distance apart that the grape berries, but not the seeds, are well crushed. Paddles revolving in a perforated cylinder below the rollers

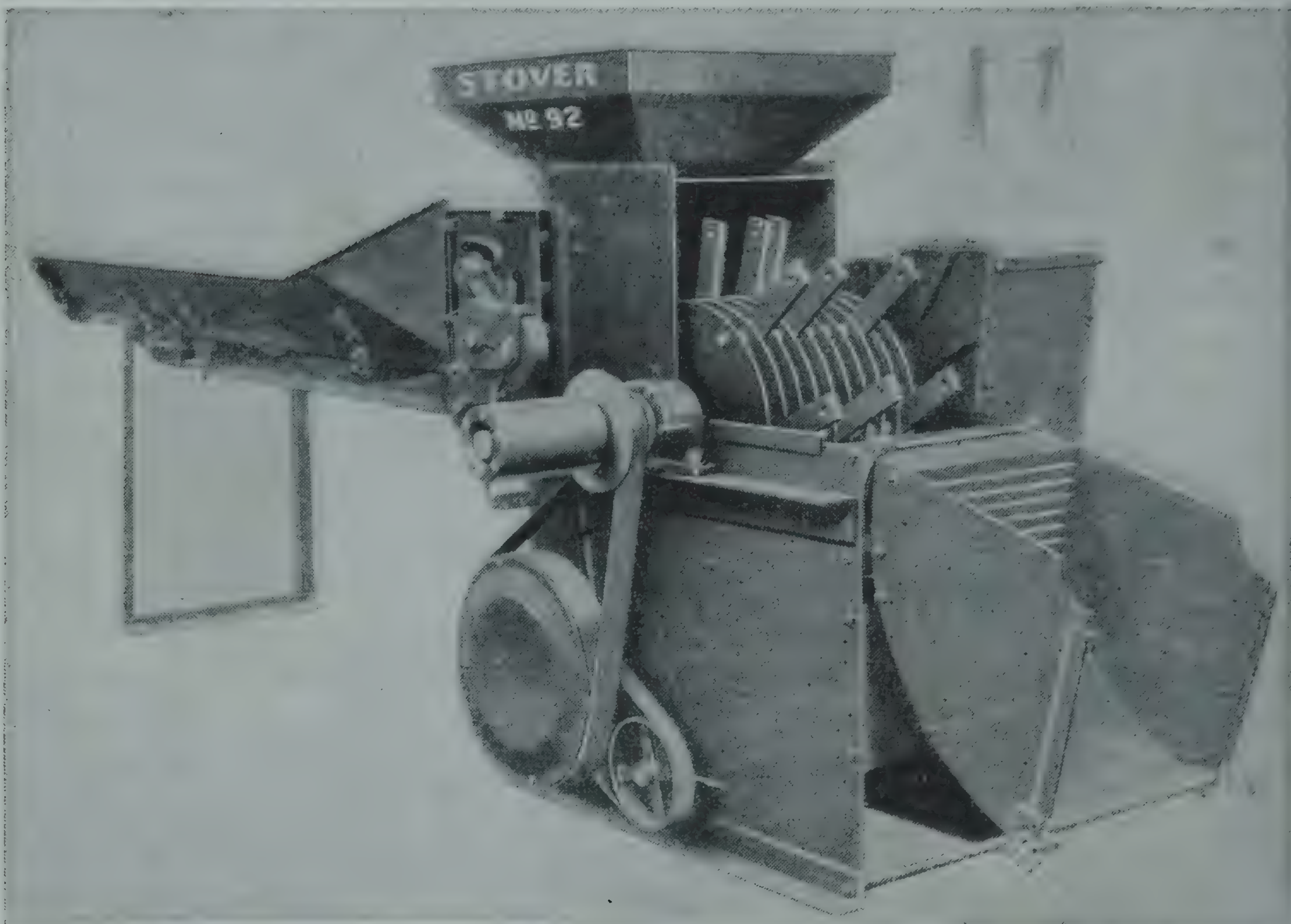


Fig. 60. Hammer-mill-type crusher for apples. (*Stover Steel and Tank Co., Freeport, Ill.*)

knock the crushed berries through the holes in the lower half of the cylinder and "kick" the stems out the open end of the stemmer cylinder. In the Garrola crusher the grapes are crushed by impact against rapidly revolving paddles inside a revolving perforated cylinder. The crushed berries and juice are pumped from the crusher to a tank or directly to the press.

Apples are prepared for pressing by treatment either in an "apple grater" or in a hammer mill. The grater consists of a revolving metal cylinder about 8 to 12 in. in diameter, on the surface of which are imbedded shallow knives extending the entire length of the cylinder. Parallel to the cylinder is a set of upright knives, or a curved fluted-metal plate toward which the cylinder revolves. The fruit on passing through the apparatus is grated, rather than crushed. The upright knives or curved plate are on heavy springs to permit passage of rocks or other hard objects. Fineness of grating is regulated by adjusting the distance between the cylinder

and upright knives or plate. This apparatus is also fairly satisfactory for grapes, berries, and pears.

At present the apple grater is being replaced by a special hammer mill. Hammers (flaillike pieces of metal) attached to a revolving cylinder crush the fruit finely. The hammers operate inside a vertical or horizontal perforated metal cylinder. The hammer mill gives a larger yield of juice than does the grater because of more thorough grinding of the fruit (Figure 60).

Citrus fruits require special equipment and procedure, as described later in the section on citrus juices. Ordinary crushing and pressing are not employed. Tomatoes are usually pressed without crushing, or they are passed between revolving and fixed metal fingers that tear them coarsely.

Pressing. Juice is extracted from most fruits by presses of many different designs, in which pressure is obtained in several different manners.

Rack-and-cloth Press. Probably the most satisfactory press for general use is that known as the rack-and-cloth press, which is used for apples. In this style of press the crushed fruit is placed in heavy cloths of coarsely woven heavy cotton fiber, to a depth of about 2 to 3 in., and the edges of the cloths are folded toward the center, as shown in Figure 59. A wooden rack made of heavy, hard wooden slats is placed on the folded cloth containing the fruit, and a second cloth containing crushed fruit is placed on this rack. The process is repeated until the press is filled. The several cloths of fruits and the racks taken together are known as a "cheese." Pressure may be applied by any one of the methods described below, although the usual method is by hydraulic pressure.

Basket Press. In the basket press, very generally used for grapes for making wine, but seldom for juice, the crushed fruit is placed in a heavily reinforced wooden basket of cylindrical form (Figure 99).

Beam Press. Pressure may be applied to either the rack-and-cloth press or the basket press in one of several ways, but the simplest method is by means of a long wooden beam weighted at one end. Pressure can be regulated by the amount of weight placed on the beam and by its length.

Hydraulic Press. Hydraulic pressure can be applied by means of oil or water and a pump. The liquid is pumped into a heavy walled "ram," or cylinder, attached to either the top or the bottom of the press. The pressure that can be applied is in the ratio of the diameter of the pressure-cylinder piston to that of the pump, and for very heavy pressures the diameter of the pump must be small and that of the cylinder large. Pressure must be increased at such a rate that the juice may escape from the cloths without subjecting the cloths to such pressure that they are ruptured. Hydraulic pressure is the usual power for rack-and-cloth as well as basket presses.

Continuous Press. All the presses described above are discontinuous in action. Continuous presses are available, into one end of which the crushed, or in some cases the whole, fruit is fed and to which pressure is applied, the pomace (pressed pulp) discharging continuously at the opposite end of the press. The juice escapes through openings in the walls of the press. In principle the press consists of a perforated cone or cylinder, hopper, and restricted adjustable opening at the end opposite the hopper, and a heavy screw that revolves within the cylinder or cone. The fruit enters the hopper at the large end of the press and is forced through the cone toward the smaller end. This press has proved fairly satisfactory for the pressing of lemons for the manufacture of citric acid and for pressing fermented crushed grapes, but it is not desirable for use in pressing most fruits because it tends to grind the fruit to a fine pulp, much of which passes through the openings in the bottom of the press with the juice. A special form of this press is used for tomatoes (Figure 76).

METHODS OF PRESERVATION OF FRUIT JUICES

Several methods are in commercial use for the preservation of fruit juices. The most important of these are discussed below.

Pasteurization. Pasteurization as applied to fruit juices means the destruction, by heat, of all microorganisms capable of increasing in the juice and of causing spoiling. It usually does not kill the spore-bearing organisms, such as thermophiles, *Bacillus subtilis*, *B. mesentericus*, etc., but these organisms and most other spore-bearing bacteria as well cannot grow in acid fruit juices, and consequently their presence is of no practical significance. Pasteurization of still (noncarbonated) juices need only be at such a temperature and for such a time that yeasts and molds are destroyed. Yeast is killed by heating for a few minutes at 140 to 150°F., and resistant mold spores will require in most cases a temperature of 175°F. for 20 min. Molds require oxygen for growth, and for this reason heavily carbonated juices can be pasteurized safely at 150°F., which destroys yeast cells. Most still juices must be pasteurized at 175°F.; juices of high acidity may be pasteurized at a lower temperature, 160 to 165°F.

Effect of Carbon Dioxide. Experiments have been made by J. H. Irish and the author to observe the effect of carbon dioxide upon pasteurizing, in which it was found that carbonating at from 10 to 60 lb. pressure did not noticeably reduce the death temperature of typical fruit-juice organisms, such as yeast, mold spores, *B. coli*, *B. subtilis*, etc. The carbon dioxide, however, prevented growth of surviving mold spores. It was found that 30 min. pasteurization at 65°C. (149°F.) in all cases prevented

subsequent development of mold spores in samples carbonated and heavily inoculated before pasteurization.

Bulk Pasteurization. It is often necessary to store fruit juices in bulk in large glass carboys or in barrels to permit settling or shipment in bulk. Two types of pasteurizers, which may be designated as (1) continuous and (2) discontinuous, are used for this purpose.

The continuous pasteurizer consists of a single metal tube or series of hollow, jacketed plates or small metal tubes, through which the juice flows and is heated to the desired temperature by a steam or hot-water jacket. Block tin, aluminum, and silver-lined copper were formerly used for the purpose; but stainless steel is much to be preferred because of its resistance to corrosion.

Plate pasteurizers are now generally used in preference to the tubular types. They consist of an assembly of stainless-steel plates with grooves on both sides. When set in a supporting frame and pressed together tightly narrow passages are formed between the plates through which the juice and the heating medium can be circulated. Turbulent flow develops with very rapid heat transfer (Figure 63).

Heating by Steam. The use of steam is somewhat objectionable because it does not permit of very exact regulation of the temperature and is liable to cause scorching or overheating of the juice. However, in the modern high-speed, high-temperature flash pasteurizers, such as the Mallory, high-pressure steam is used very successfully, as the period of exposure is very short.

Heating by Water. If the heating plates or tubes of the continuous pasteurizer are surrounded by water, it is possible to regulate the temperature very closely. The temperature of the water surrounding the heating tubes need not be more than 3°C. (about 6°F.) above the temperature of the juice, and therefore there is little danger of overheating the juice.

Discontinuous Pasteurizers. The discontinuous pasteurizer consists of a steam-jacketed kettle, or of a tank equipped with steam coils, in which the juice may be placed and heated to the desired temperature. It is objectionable because it is liable to cause local overheating of small portions of the juice in contact with the heating surface, to expose the juice to the air and oxidation during pasteurization, and to prolong heating with injury to color and flavor.

Heating by Electricity. In the Electropure apparatus the fruit juice is passed between carbon electrodes; at the same time the juice is heated almost instantaneously to the desired temperature by passage of ordinary 110-volt 60-cycle alternating current. This method is easily regulated and avoids scorching. Heat is generated by passage of current against the resistance of the juice; the electrodes themselves are not hot.

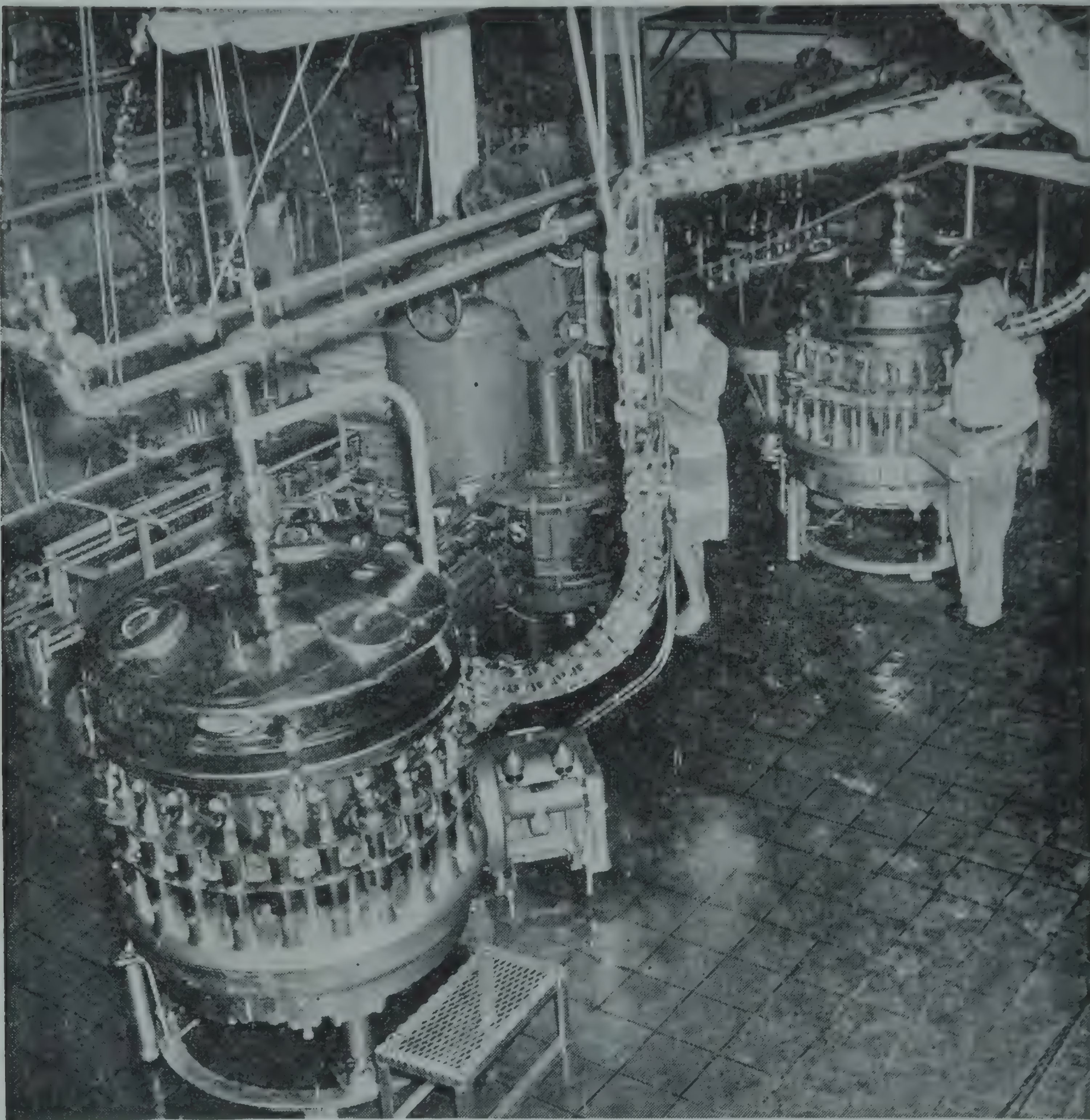


FIG. 61. Filling cans with hot juice. (*Western Canner and Packer.*)

Flash Pasteurization and Cooling. Under usual factory conditions the juice in bulk pasteurization is passed, while still hot, directly into sterile barrels or large bottles for storage and remains hot in the barrels for 24 hr. or longer and in the bottles for 5 or 6 hr. This prolonged heating results in considerable injury to the flavor and the color of the product.

Chace has devised a means of chilling the juice immediately after pasteurization by passing the cooled juice under aseptic conditions into sterile containers, preferably bottles, and sealing the containers with sterile corks or caps. Great care must be employed to avoid infection of the juice with mold or yeast, and it is doubtful whether the process will have wide application in factory practice. A temperature of 180 to 195°F. (about 82 to 90°C.) is used for a few seconds only, and therefore the juice suffers very little injury to flavor or appearance. Some present flash

pasteurizers heat the juice momentarily to 240°F. or higher; but it is cooled to 190°F. or lower before filling for fruit juices and to about 210°F. for tomato juice. This treatment is given to citrus juices and apple juice to inactivate enzymes, as later described.

Much juice is now filled at 175 to 180°F. into bottles or cans, which are sealed at once and rapidly cooled. This method is simple and on cooling gives a head space practically devoid of air.

Pasteurization in Bottles and Cans. Although this method has been very largely replaced by the "hot-fill-hold-cool" method, it will be described briefly. After the juice has been filtered or otherwise treated to prepare it for bottling or canning, it is sealed in the final container and pasteurized, usually by immersion in water, which is heated to the desired temperature and for the desired length of time. One form of bottle pasteurizer consists of a shallow wooden vat fitted with a steam coil and a perforated false bottom on which the bottles are placed in a horizontal position, covered with water, and heated to the pasteurizing temperature. Experiments are being made in several laboratories on sterilization of juices by high-frequency radio waves for heating the product.

In large establishments continuous pasteurizers are used in which the bottles of juice are carried by a basket conveyer progressively through baths of water of increasing temperature and through baths of water of decreasing temperature to cool the juice. Cans are usually filled hot directly from a bulk pasteurizer or are pasteurized in a continuous pasteurizer in much the same manner as canned fruit is processed. Bottles are also now filled hot, sealed, and given no further heating.

Heat may also be applied to the bottled juice by sprays of water circulated by a pump. The temperature may be regulated so that the bottles are heated gradually to the pasteurizing point and cooled slowly so that breakage is reduced to a minimum.

Relation of Factory Sanitation to Pasteurization. Investigations at the University of California have demonstrated that the temperature necessary for pasteurization varies with the mass of the infection of the juice with yeast or mold.

Therefore all possible precautions should be taken to exclude microorganisms from the juice at all stages of the process. Press cloths, unless washed immediately after use and dried at once, will become "sour," i.e., infected with large numbers of yeast cells and mold spores. The lines, pumps, tanks, filling machines, and all other equipment that comes in contact with the juice must be kept scrupulously clean with steam or hot water used frequently and generously in cleaning and sterilizing it. Crushers are particularly liable to develop yeast and mold if not thoroughly cleaned after use.

Bottles, cans, and bottle caps should be sterilized before use, caps in

particular being a very prolific source of mold infection in bottled beverages.

Preservation of Fruit Juices by Chemical Preservatives. Although it is not an ideal method of preservation, large quantities of apple juice are preserved with benzoate of soda. Other fruit juices are sometimes preserved with sulfurous acid.

Benzoate of Soda (and Benzoic Acid). The active preservative principle of benzoate of soda is the undissociated benzoic acid, not the sodium salt. The salts of benzoic acid are more readily soluble than the acid, and for this reason the sodium salt is employed in preference to the acid.

The percentage of sodium benzoate that may be used in the preservation of foods was at one time limited by pure food and drug regulations to $\frac{1}{10}$ per cent, but at the present time more than this amount may be used, provided the label bears a statement giving the percentage contained in the product. Fruit juices can, in practically all cases, be preserved satisfactorily by the addition of $\frac{1}{10}$ to $\frac{15}{100}$ per cent of the benzoate. The benzoic acid exerts a selective action upon the organisms found in sweet cider, often preventing the growth of yeasts and molds, but permitting the development of vinegar and lactic acid bacteria.

Carbonating increases the toxicity of benzoic acid upon the spores of *Bacillus subtilis*, as shown by investigation by J. H. Irish on the carbonating of grape juice. pH value greatly affects the preservative action of sodium benzoate, the preservative action being much greater at low than at high pH values.

Sodium benzoate possesses a disagreeable "burning" taste that is readily perceptible in juice containing $\frac{1}{10}$ per cent of the benzoate.

Sulfurous Acid. Fruit juice can be preserved for more than a year by the addition of $\frac{1}{10}$ per cent of sulfurous acid (1,000 mg. per liter, or 1,000 parts per million), provided the juice is made from sound fruit and stored in clean containers at a temperature not above 60°F.

Sulfurous acid is very much more toxic to mold spores and vinegar bacteria than it is to yeast, in this respect differing from benzoic acid, which is more toxic to yeast than to vinegar bacteria.

Fruit juice may be preserved temporarily (from several days to 2 or 3 weeks) with concentrations of sulfurous acid considerably less than $\frac{1}{10}$ per cent, and small amounts of this preservative are often useful in preventing fermentation of juice during 1 or 2 days' settling after pressing, in order to aid in clearing. For this purpose 100 mg. per liter (0.01 per cent) of sulfurous acid is usually sufficient and does not noticeably affect the flavor of the product.

Disappearance of Sulfurous Acid. Some of the preservative combines with the sugar and other compounds of the juice and in such a form is not perceptible to the taste. Part of it either escapes into the atmosphere

as sulfur dioxide or is oxidized to sulfuric acid, H_2SO_4. Bioletti and Cruess (1913) studied the rate of disappearance of sulfurous acid from grape juice and the rate of conversion of free sulfurous acid into the combined form. Cruess, Richert, and Irish (1931) found that combined sulfurous acid has very little antiseptic value upon microorganisms, 6,000 parts per million (p.p.m.) of the combined form having less toxic action on yeast than 50 p.p.m. of the free sulfurous acid.

The presence of a very small concentration of sulfurous acid, e.g., 50 to 100 mg. of sulfur dioxide per liter in fruit juice, greatly aids in the preservation of the fresh fruit flavor and color by reducing the tendency of the juice to oxidize. It cannot be used, however, in juice that is to be stored in tin or other metal containers, since in contact with metal the sulfur dioxide is reduced to hydrogen sulfide with the development of a disagreeable flavor. Sulfurous acid can be removed by heating the juice to about 70°C. (about 160°F.) and passing through it a vigorous stream of air, or by passing steam through the juice under vacuum.

Sugar as a Preservative. All fruit juices may be preserved by the addition of sugar or by increasing the natural sugar content of the juice by concentration. Such products are, however, fruit sirups and will be discussed fully in Chapter 13.

Preservation by Low Temperatures. At 32°F. (0°C.), the temperature ordinarily employed in the cold storage of fruits, fruit juices either become moldy or undergo fermentation. In order to prevent the growth of microorganisms, it is necessary to store them at temperatures below 25°F.

In experiments at the University of California (Cruess, Overholser, and Bjarnason), it was found that grape juice, apple juice, and berry juices could be held for at least 2 years at temperatures of 10 to 15°F. (about 5 to 8° below 0°C.) without noticeable loss of flavor, aroma, or color, where the juices were stored in sealed containers, such as lacquered tin cans or in bottles. The juices were not pasteurized. In recent experiments various fruit juices and "nectars" were preserved very satisfactorily at 0°F. for a year or more. Orange and grapefruit juices lend themselves extremely well to this method provided air is excluded. Very large quantities of 3-plus-1 concentrates of these and other juices are preserved by freezing (Chapter 25).

Fruit juices have been preserved by cold storage for shipment over a distance of 500 miles in glass-lined tank cars by precooling the juice to about 28°F. and placing it at once in well-insulated tanks of several thousand gallons' capacity each.

Preservation by Pressure. Hite, Giddings, and Weakley found that grape juice in active fermentation could be sterilized by subjecting it to a pressure of 75,000 lb. per sq. in. for 30 min. and by a pressure of 30,000 lb. per sq. in. applied for a somewhat longer time. Apple juice was sterilized

by 60,000 to 80,000 lb. pressure per sq. in. where applied for 30 min., and actively fermenting sugar solutions were sterilized by 60,000 lb. pressure in 30 min.

In these experiments a small collapsible tin tube was filled with the fruit juice or other liquid, and the tube was sealed. The tube was then placed in a lead cylinder, which in turn was placed in a heavy-walled steel cylinder into which water or oil was forced by hydraulic pressure. In some of the experiments a pressure of 110,000 lb. per sq. in. was used.

The experimenters state that fruit juices preserved by this method were equal to the fresh fruit in flavor and general quality and that it would be feasible to build a machine in which juice could be sterilized in containers of larger size than those used in their experiments.

Preservation with Carbon Dioxide. Fruit juices have been successfully preserved by special methods of carbonating. In the Ruef process the fruit juice is first run through a porcelain filter to remove most of the yeast cells, then carbonated under aseptic conditions, and placed in sterile bottles. The method has not been applied commercially because of the great difficulty of completely excluding microorganisms.

In Europe much apple juice is preserved in bulk in glass-lined tanks by first germproof filtering and then impregnating with carbon dioxide to about 100 to 110 lb. pressure. See later section in this chapter on this method, known as the Boehe, or Seitz-Boehe, process.

Preservation by Close Filtration. In Germany, America, Switzerland, and South Africa, fruit juices have been successfully preserved by filtration through "tight" pads such as the Seitz E-K filter pads under aseptic conditions into bottles sterilized with sulfur dioxide solution. This procedure is in use in several plants in Europe. Experimentally, as previously mentioned for the Ruef process, juices have been rendered free of microorganisms by filtration through a fine-pored Berkefeld porcelain-filter candle.

The trend in America at present, however, is toward cloudy or pulpy juices, except for apple juice.

Control of Enzymes. Preservation of the flavor, aroma, color, and vitamin content of the fresh juice is dependent to a great degree on destruction of certain enzymes or inhibition of their activity.

Joslyn and Marsh have found that flash pasteurization at about 190 to 195°F. destroys the enzyme or enzymes responsible for many of the undesirable changes in flavor and the curdling of citrus juices. Matthew and the author found that small concentrations of sulfur dioxide also retarded these changes, indicating that oxidation is involved, at least to some extent. Addition of vitamin C retards oxidation and protects aroma and flavor.

Apples contain a very active oxidase. Thus it is desirable to flash pas-

teurize the fresh juice immediately after pressing, in order to minimize browning by destruction of the oxidase responsible for this change. Vitamin C is rapidly destroyed during darkening of fresh apple juice.

Pederson (1947) found that the addition of ascorbic acid during crushing prevented browning of the juice and improved the flavor and aroma. Strachan and Atkinson (1949) have extended its use under Canadian conditions very successfully.

Subjecting freshly expressed juices to a high vacuum for 15 to 20 min. to remove dissolved and occluded oxygen before canning or bottling greatly reduces subsequent undesirable oxidative changes. In the canning of citrus juices deaeration in this manner is common practice and has also been applied in tomato-juice factories. In some plants the vacuum is released with nitrogen gas instead of with air in order to minimize oxidation still further.

Filling the bottles hot and sealing them completely full and hot excludes most of the air and thereby minimizes subsequent oxidation. Juices should be canned or bottled promptly to avoid excessive changes due to enzyme action.

In short, as many precautions as possible must be taken to curb enzyme action during the preparation of fruit juices and also to prevent their activity after canning or bottling.

THE FILTRATION OF FRUIT JUICES

Some fruit juices are improved in appearance by filtration or by other means of clarifying. The exceptions to this rule are citrus, apricot, peach, pineapple, pear, and tomato juices, which are most popular in the cloudy condition.

Bag Filter. The simplest filter is that known as the bag filter, which is merely a conical bag made of canvas, felt, or other heavy cloth. Unless the juice is mixed with infusorial earth or other clarifying material it does not usually yield a clear juice. This filter is useful for a preliminary treatment of juice to be filtered through a more effective type of filter or in the home preparation of juice.

Pulp Filter. The usual form consists of an upright copper or stainless-steel cylinder filled with several thick disks of compressed wood pulp or cotton fiber. Circular metal screens and metal plates are placed between the pulp disks and so arranged with regard to the juice-supply pipe and outlet pipe that each disk acts as an individual filter. The juice is forced through the filter by gravity from a supply tank above the filter or by means of a force pump. The filter mass or pulp must occasionally be removed and washed thoroughly and can then be formed into filter disks for use again. The clearness of the filtrate and rate of filtration depend to a

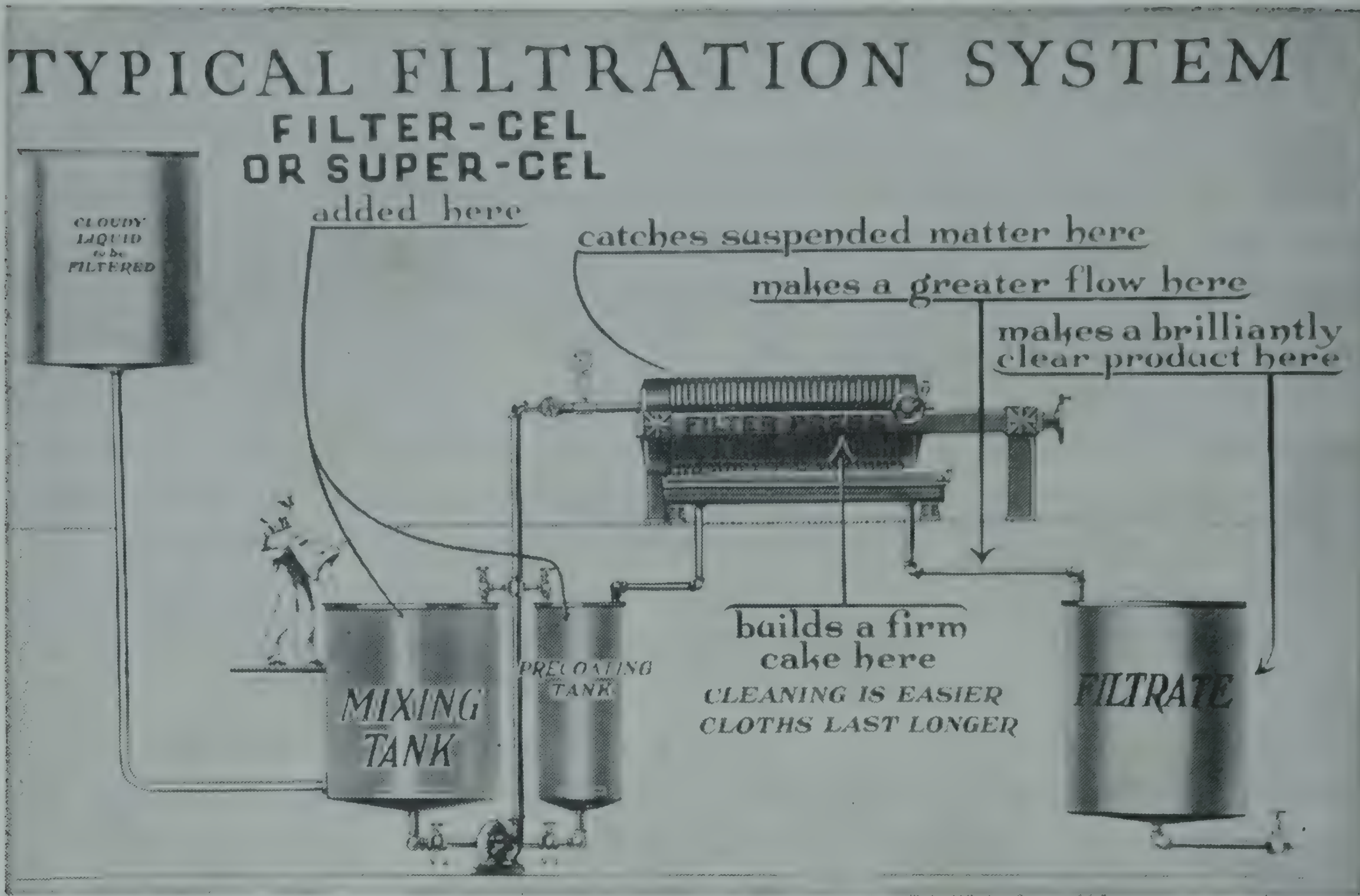


FIG. 62. Schematic flow sheet for filtration of juices, etc., with filter aid. (*Johns Manville Corp.*)

large extent upon the pressure applied in forming the filter cakes. Thus through heavily pressed disks, filtration will be slower and the filtrate clearer than if the pulp is formed into cakes under low pressure.

For small-scale use a large suction funnel, in which a layer of pulp is packed as a filter mass, is satisfactory. It may be attached to a large, widemouthed bottle and a suction pump.

Filters are also packed with short-fiber asbestos. The Seitz filter is of this type and consists of an upright chamber in which is enclosed a screen coated with a layer of asbestos fiber. The clearness of the filtrate can be regulated by the length of the fiber used. Short fiber mixed with ground asbestos or infusorial earth is used for producing a brilliantly clear filtrate, whereas the longer-fiber asbestos is used for coarse filtration. The asbestos may be washed and used repeatedly.

Pad Filter. The pad filter, a form of filter press, has become popular in the wine and brewing industries for final or "polishing" filtration of wine and beer. It has been used also, as previously stated, for sterilization of fruit juices by complete removal of all microorganisms. The Seitz pad filter is the best known of filters of this type and is widely used in Europe. The Ertel, Columbia, Hercules, and Alsop, American pad filters, are also excellent.

The pad filter consists of a number of recessed metal frames between

which are held thin pads made of pulp and asbestos fiber. The pads are purchased ready to use from the manufacturer and are discarded after use. Pads are of varying degrees of porosity. Ordinarily the juice first is given a rough filtration in some other form of filter, and the pad filter is used as a means of making the juice brilliantly clear.

Filter Press. The usual filter press consists of a series of metal or wooden plates between which are placed pieces of canvas or other heavy cloth, each piece of canvas and pair of plates acting as an independent filter, although all the plates are fed from a common source (Figure 62). Aluminum bronze has proved very satisfactory for construction of the plates and frames, since it is resistant to corrosion and has sufficient strength for the purpose.

In operating the filter press some of the juice is mixed with a small amount of infusorial earth, which collects on the surface of the filter cloths, forming a filter mass and effectively removing suspended matter from the juice. Also, a small quantity of infusorial earth is added continuously and automatically during operation.

Screen Filter. In the wine industry, filters consisting of fine stainless-steel screens on which a layer of infusorial earth acts as a filter are commonly used. The filter aid is added to the wine. These filters can also be used for juices.

Effect of Preliminary Heating on the Filtration of Juices. Fresh fruit juice is rather slimy in character and extremely difficult to filter. Preliminary pasteurization reduces the viscosity of the juice, and 24- to 48-hr. settling usually results in the coagulation of much of the protein and gums of the juice and its elimination by settling, together with a large proportion of the suspended, finely divided pulp. However, in some cases such treatment renders the juice more difficult to filter.

Infusorial Earth as an Aid to Filtration. Chace has described a process of clarification of pomelo (grapefruit) juice with infusorial earth and filtration. He recommends the building up of a thick layer of the earth on a fine metal screen or heavy denim filter cloth in some form of filter press, and mixing with the juice to be filtered 5 or 6 lb. of the earth per 100 gal. In practice usually less than this is used. A commercial filter, the West Coast, makes use of a fine screen and infusorial earth. Plate-and-frame filter presses fitted with canvas or heavy-cloth filter cloths are commonly used (Figure 62). The producers of the infusorial earth are now in a position to furnish the incinerated earth in form suitable for the filtration of fruit juices.

Infusorial earth is mined as a white, friable, and easily powdered rock. The principal deposit and mine are located at Lompoc and elsewhere in California. The rock is ground to a fine powder and separated into powders

of different degrees of fineness by sifting and air flotation. It is known in the trade as Filter-Cel, Hy-Flo Supercel, Dicalite, etc.

CLARIFICATION OF FRUIT JUICES BY SETTLING, BY FINING, AND BY ENZYMES

It is possible in certain cases to clarify fruit juices by settling, with or without pasteurization as the juice may require, or by the addition of fining materials.

Settling. Frequently fruit juices after pasteurization will become clear

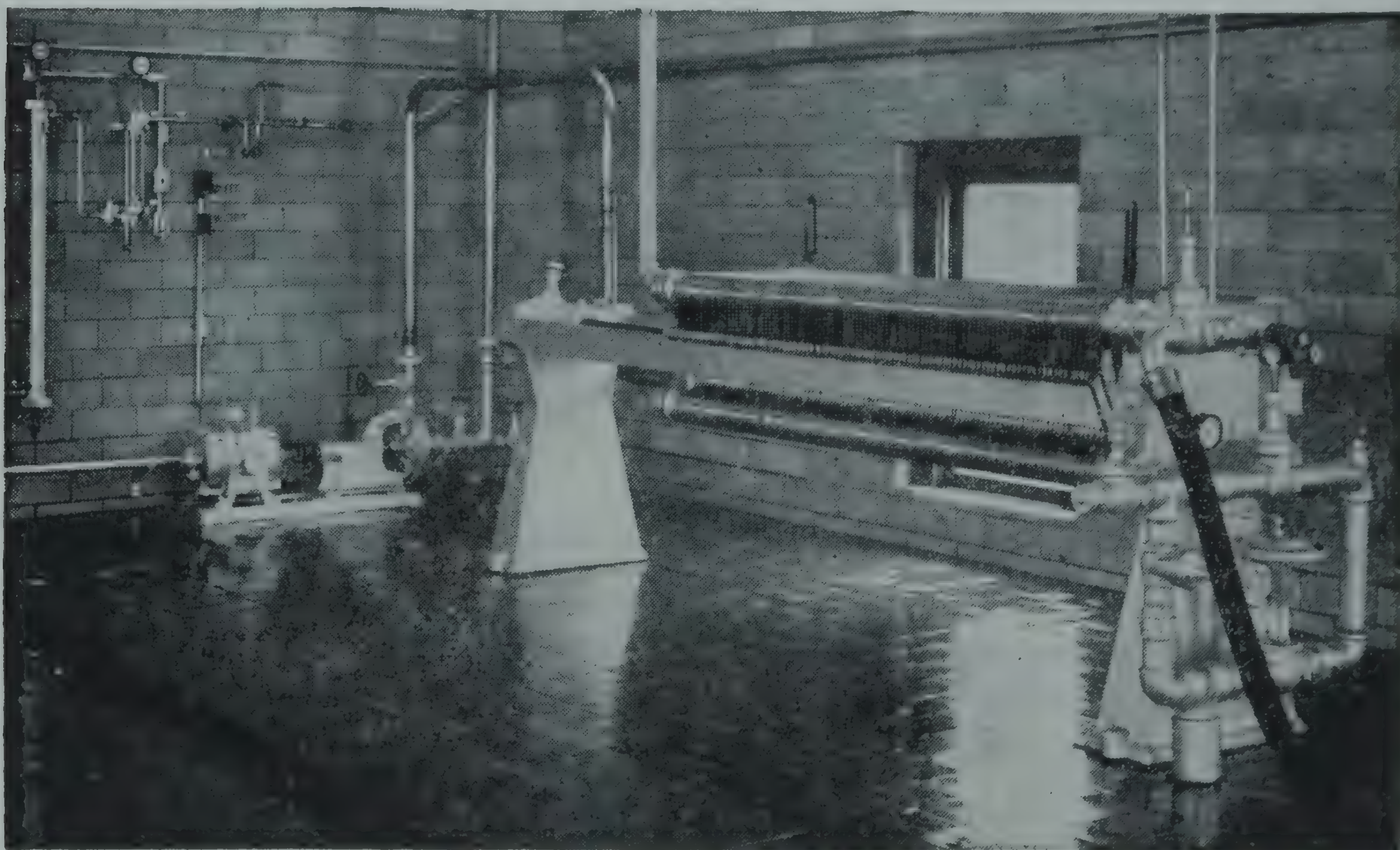


FIG. 63. Plate-type APV pasteurizer and heat interchanger. (*Walter-Wallace Co.*)

during storage, the length of storage necessary depending upon the variety of juice and other conditions. Thus pomegranate juice will become clear within 24 hr. after pasteurization, while grape juice usually requires several months' settling.

In the commercial manufacture of grape juice, settling of the pasteurized juice greatly facilitates filtration by eliminating much suspended matter.

Use of Finings. Some juices that do not settle satisfactorily during storage and are difficult to filter can be clarified by the addition of a fining agent. This agent may be defined as a substance that, when added to the liquid to be clarified, will form a precipitate which settles and carries with it the finely divided particles responsible for the cloudy appearance. The fining materials most commonly used for fruit juices are egg albumen, casein, bentonite clay, and infusorial earth.

Egg Albumen. This is purchased in dry granular form and is dissolved in warm water by soaking and agitation. The temperature of the water must not be high enough to cause coagulation of the albumen, and the best results are obtained with a 2 per cent solution. Red juice from Vinifera grapes (European varieties) normally requires about 100 to 150 grams of albumen (dry basis) per hectoliter (about 3⅓ to 5 oz. per 25 gal.), and Muscat grape juice requires about 200 grams of albumen per hectoliter. Preliminary tests with small lots (500 cc. each) of the juice should be made to determine the amount of finings required. The required amount of the finings solution is mixed with the juice, and the whole is heated to a temperature of 160 to 175°F., coagulating the egg albumen, which settles rapidly during subsequent storage. Some of the albumen apparently remains in unstable solution for several days but finally precipitates. The juice should be heated with the finings to a temperature several degrees above that to be used for the bottled juice, in order to avoid further coagulation of albumen and clouding in the bottle.

Casein. Commercial casein is prepared from skim milk by precipitating the curd (casein) with dilute hydrochloric or other acid; separating of the curd from the whey; and washing, drying, and grinding the resulting casein. It is soluble in alkalies and is precipitated from solution by acids. For the clarification of fruit juices a 2 per cent solution is prepared by soaking the casein in a small amount of ammonium hydroxide solution (concentrated ammonia diluted with 10 to 20 parts of water) and boiling until fumes of ammonia are no longer perceptible. The solution is then diluted to 2 per cent casein content and is added to the juice as noted above for egg albumen. However, this procedure is no longer necessary as water-soluble caseinates, excellent for clarifying, are now available. The acid of the juice precipitates and coagulates the casein, and the coagulum usually settles completely within 24 to 48 hr. after pasteurization. It is less likely than egg albumen to precipitate in clarified juice after bottling, and it exerts considerable bleaching action on red juices.

Bentonite Clay. Bentonite clay occurs in abundance in Wyoming. It is used for the clarification of wines and vinegars and has been used to a limited extent in the clarification of fruit juice. It is purchased as a powder and is mixed with water to give a finely divided suspension, containing about 5 grams of the clay per 100 cc. The suspension should be allowed to stand for several days to permit complete dispersal of the clay. This "solution" is added to the juice at a rate to give 2 to 3 grams of clay per liter. The juice should be heated to or above 140°F. to hasten coagulation and settling.

Juices successfully clarified by means of any of the foregoing fining materials can be filtered easily, giving brilliantly clear filtrates. However, in the clarification of juices commercially the usual procedure is to treat the

juice with a pectic enzyme for several hours or overnight, followed by filtration. See the next section and also the clarification of apple juice with pectic enzymes.

Use of Enzymes. It was found by Kertesz of the New York Agricultural Experiment Station that apple and grape juices could be clarified satisfactorily by treatment with an enzyme preparation from certain molds. The principal enzyme concerned is a pectic enzyme. It is added to the fresh juice, which is then allowed to stand long enough for the enzyme to exert its clarifying action, usually 8 to 16 hr. The length of application depends upon the amount of enzyme used and the temperature of the juice. Pectin is hydrolyzed, and the treated juice is then easily filtered. This method is in general use, not only in the United States and Canada, but also in European countries.

According to Marshall, apple juice clarified with a pectic enzyme may deposit a sediment after bottling and storage unless the juice is pasteurized at a high enough temperature to destroy the enzyme or if the enzyme has not been allowed to act long enough (see Marshall's report and the section in this chapter on apple juice).

BOTTLING OF FRUIT JUICES

Clear fruit juices are very attractive in glass containers, a fact that aids naturally in direct advertising to the consumer.

Preparation of the Bottles. Bottles should be scrupulously clean and should be sterilized in live steam before use. Even a thoroughly rinsed bottle may contain a considerable number of mold spores and yeast cells. Large mechanical bottle soakers and washers are available that wash the bottles thoroughly in dilute lye solution and rinse them in water.

Caps. The commonest and least expensive closure for bottles is the Crown cap, long used for bottled soda water, beer, and fruit juices. It consists of an outer metal disk, an inner cork disk that rests against the top of the bottle and makes the seal, a shellacked paper disk between the cork and metal disks, and usually a shellacked paper disk, known as a "spot," on the outer surface of the cork. The innermost disk binds the metal and cork disks together. The cap is crimped to the bottle by compression in a Crown capping machine. Modern caps have a shellacked or plastic-coated paper disk that rests against the lip of the bottle. It is also known as a spot.

The Goldy cap is similar to the Crown cap but consists of an inner cork disk and two outer metal pieces, one of which is made of aluminum and can be torn from the bottle with the fingers. The White cap is held in place by friction or vacuum; its heavy soft-rubber gasket makes an air-tight seal.

Corks were once used, particularly for heavily carbonated juices, but they require the use of clamps during sterilization to prevent them from being forced from the bottles and are more expensive than caps.

Caps with cork liners or corks should be sterilized in steam before use in order to kill mold spores.

Carbonation. Bottled juices are usually more pleasing if carbonated. This may be accomplished in a continuous carbonator or in a bulk carbonator. In the latter the juice is carbonated at low carbon dioxide pressure in glass-lined tanks at about 30 to 32°F. In the former, the juice and carbon dioxide are mixed in a special chamber as the juice flows from the supply tank to the bottling machine.

Suitable carbonating and bottling equipment for carbonated juices can be had from any soda-water-bottlers supply company. Stainless steel or other resistant metal must be used.

Experiments by the author have shown that beer cans may be used successfully as containers for carbonated fruit juices.

Filling Machines. Bottles are usually filled by automatic or semiautomatic machinery. For the small-scale bottling of fruit juices a hand-operated filler attached to a hose may be used.

In one type of can-filling machine for juices the cans are fed by gravity chute to a circular revolving platform, each can being held accurately in place. As the platform rotates each can in turn is elevated until it rests tightly against a circular base plate of a filling valve connected to the juice reservoir above. The pressure of the can against the base plate opens the valve, and juice then flows into the can. The displaced air from the can rises through a vent and escapes to the atmosphere. When the liquid in the can reaches a predetermined level the outflow of air is cut off and the flow of liquid stops (Figure 61).

In another type of can filler a definite volume of liquid is measured in a chamber above the valve. When the can is raised until it presses against the base plate the valve is opened and the measured volume of juice flows into the can. The can is open to the air.

Automatic bottling machines for juice operate on principles similar to those used in can fillers and resemble bottling machines used for beer or soda water.

Filling machines must be cleaned thoroughly after use in order to avoid development of mold and yeast during periods of idleness, and hose and other filling equipment should be thoroughly flushed with water and steamed before use.

GRAPE JUICE

The grape districts of New York, Ohio, and Washington produce most of the bottled grape juice in the United States. The total annual production

for the United States is estimated at about 4,500,000 cases, according to *Western Canner and Packer*.

Varieties of Grapes for Juice. The Labrusca varieties are grown in New York and in the Middle West and the Vinifera varieties in California. The Labrusca varieties, such as the Concord, possess more acid and a more marked and characteristic flavor and aroma than the Vinifera varieties. Lack of distinctive character has made it difficult to market Vinifera juices.

Labrusca. The Concord is the most popular of the Eastern or Labrusca varieties, and most of the bottled grape juice on the market is prepared from this variety. The Pierce Isabella is also excellent for juice. Dearing recommends it very highly and states that it produces a juice which is of more intense color and is more easily clarified than Concord juice.

Pederson (1954) states that the Concord is to be preferred to other varieties because of its regular, better-than-average bearing, its adaptability to Eastern and Middle Western conditions, the deep, stable red color of its heat-extracted juice, its rich flavor, stability against sedimentation, and the proper balance between the acidity, sugar content, flavor, and astringency of its juice. He mentions the Ives, Clinton, Fredonia, and Van Buren as being reasonably good for red-juice production, and the Niagara, Ontario, Delaware, Catawba, and Seneca for white or pink juices.

Vinifera. Of the Vinifera (European) grapes grown on a commercial scale in California, the Muscat (a white raisin grape) is the only one possessing a very pronounced flavor, although the Semillon, Colombard, and Riesling have pleasing but delicate flavors. The Zinfandel, Petite Sirah, and Alicante Bouschet, all commercially grown Vinifera varieties, can be used satisfactorily with the Muscat to furnish the necessary color.

Muscadine. In the Southern states the Scuppernong or Muscadine varieties, grapes of pronounced flavor, are grown extensively. Dearing has found the Thomas variety one of the best for juice because of its high acidity, flavor, and sugar content. Others suitable for juice, according to Pederson, are Hunt, Murphy, Pickett, Yuga, Cowert, and Scuppernong. The Thomas, Scuppernong, and Latham varieties produce white or yellow juices; red juices are obtained from the James, Mish, and Luola.

Harvesting. Labrusca varieties grown under Eastern United States conditions should be picked when they have reached full maturity, maximum flavor, and color. The same applies to the Scuppernong varieties.

The Muscat should be picked at about 23° Balling, and the red varieties that are to be blended with the Muscat should be picked while still of high acidity, viz., at 18 to 20° Balling.

Storage. Hartmann and Tolman have recommended that crates of Concord grapes be allowed to stand for about 24 hr. before crushing in order to promote improvement of flavor and aroma. Vinifera varieties, such as the

Muscat, Zinfandel, etc., should be crushed as promptly as possible after picking.

Washing. In Eastern United States plants the grapes are thoroughly spray-washed before crushing.

Crushing and Pressing. Red grapes are crushed and stemmed. The stems must be removed because they impart a harsh flavor to the juice if they are heated with the skins for color extraction. White grapes should not be stemmed, since the stems will aid in pressing, and as the grapes are not heated before pressing the stems do not affect the flavor of the juice.

Heating. The crushed, stemmed red grapes are heated to extract the color. Pederson recommends a temperature of 140 to 145°F. At higher temperatures an excessive amount of tannin and harsh flavor are extracted from the seeds. With Vinifera varieties in California good results were obtained by heating to 160°F. for 5 min. only. One commercial method consists in heating the crushed, stemmed grapes in a continuous pasteurizer equipped with tubes of large diameter, holding a few minutes and pressing hot. The recommended temperature is 145 to 150°F.

Pressing. In the Concord grape district rack-and-cloth presses are used. Infusorial earth is sometimes added to the crushed grapes to improve pressing.

The pomace from heated grapes is equal to about 15 per cent of the weight of the original grapes and contains about 60 per cent moisture and about 40 per cent solids. That from unheated grapes is usually about 20 per cent of the weight of the fresh grapes because pressing is less complete than with heated grapes.

The pomace is usually discarded, but it is suitable for stock food or for the manufacture of such by-products as jelly, brandy, salad oil, tannin, and cream of tartar. The stems can be used as a source of tannin and tartaric acid but are usually discarded.

Sterilizing. The juice is strained through a screen or cloth to remove coarse pulp and in most factories is then heated to 180 to 190°F., transferred to large glass carboys or stoneware jugs, and stored for several months to a year to allow deposition of surplus cream of tartar.

Heating is for the purpose of pasteurizing; the lower the temperature at which this can be safely accomplished, the better the quality of the juice will be; but the temperature must be high enough to destroy mold spores, normally not less than 175°F.

The continuous pasteurizer is preferable because it is more convenient and does not permit so great a drop in temperature between the pasteurizer and storage container as occurs with discontinuous pasteurizers.

Carboys. The carboys should be thoroughly steamed before use and should be hot at the time of filling. They are filled almost completely so that foam will be discarded in the overflow, and then sealed immediately

with corks sterilized in hot paraffin, which prevents entrance of air and microorganisms during storage. The corks should be covered with melted paraffin after the carboys are corked.

Barrels. The 50-gal. barrels formerly used as storage containers in California are objectionable because they impart a woody taste to the juice, permit slow oxidation with loss of color, and are difficult to seal against infection. Since juice remains hot in the barrels for 24 hr. or longer, the result is a loss of flavor and color.

Glass-lined Tanks. In New York State glass-lined steel tanks or wax-lined concrete or wooden tanks are now used to an increasing extent. They should be located in a cold room at 28 to 30°F. to hasten deposition of cream of tartar and to retard mold growth. The juice should be flashed-pasteurized in order to eliminate yeasts and mold spores. The hot juice is precooled in two stages: first in a water-cooled heat exchanger, and then in an ammonia- or Freon-cooled refrigerating unit to about 27°F.

Storage. Storage is for the purpose of permitting separation of excess cream of tartar, acid potassium tartrate, $KH(C_4H_4O_6)$, and settling of suspended solids, much of which represent coagulated proteins. The temperature of storage should be low, not above 32°F., in order to hasten separation of cream of tartar and to minimize danger of fermentation or molding. Molding is the greater hazard. Ultraviolet lamps placed above the juice are sometimes used to inhibit mold growth.

Hartmann and Tolman have studied the changes in composition of Concord grape juice during storage. They found the following decreases during 4 months' storage: nonsugars 0.51 per cent, sugars 0.10 per cent, total acidity 0.13 per cent, cream of tartar 0.25 per cent, ash 0.12 per cent, and tannin plus coloring matter 0.04 per cent.

If the juice is not held under refrigeration, separation of the cream of tartar is slow, and at least 6 months' storage is usually necessary. At 32°F., 3 or 4 months' storage is usually sufficient. See also the freezing process of quick removal of tartrates, presented in a subsequent paragraph. If the juice is treated with a pectic enzyme as described for apple juice and filtered, separation of cream of tartar is greatly hastened.

Large stainless-steel tanks are much to be preferred to glass carboys for such storage.

Racking. The settled juice is separated from the sediment by siphoning by means of a U-shaped tube attached to a flexible rubber hose. The U tube is inserted through the mouth of the bottle or barrel to a short distance above the sediment, and gentle suction is applied to siphon the juice into a suitable container. Draw-off tubes are used in the tanks.

The sediment, consisting largely of cream of tartar, is strained through cloth to separate it from the juice and may be dried for sale to cream-of-

tartar factories. The sediment is often centrifuged to give a cloudy juice and semidry cake of "argols," the crude cream of tartar.

Filtering and Fining. In Eastern factories the juice is usually only roughly filtered, whereas in California it was formerly usually fined with egg albumen or casein, as described earlier in this chapter, and subsequently filtered. At present filtration is used.

Vinifera juices can be filtered very much more easily than Labrusca juices, since the latter are very rich in pectin and gums, hence viscous and difficult either to fine or filter. Pectic enzymes are very useful for treating such juices.

Bottling and Pasteurizing. Grape juice is usually bottled as a still (not carbonated) juice. Quart, pint, and 4-oz. bottles sealed with Crown caps are the usual containers. Bottles and caps must be clean and should be sterilized in steam before filling, in order to destroy mold spores.

The bottled juice may be pasteurized in water, usually for 30 min. at 175 to 180°F., and should be cooled after pasteurizing in order to check the deleterious effect of heat on the color and flavor of the juice. Pederson and others have shown that color is much better if the bottles are filled to overflowing at about 180°F., sealed, and cooled, as oxidation after bottling is thereby minimized. This is now common practice. Pederson recommends that the temperature of the juice after bottling be at least 170°F.

Quick Process for Bottled Juice. It is possible to freeze fresh juice to a mushy mass of ice crystals and sirup by 24-hr. storage at 0 to 15°F. This treatment causes immediate separation of excess cream of tartar, which can be removed after allowing the frozen juice to melt. The juice can then be filtered and bottled. The entire process requires about 48 hr. from crushing to bottling. Its use would greatly reduce the storage space and containers now employed in the sedimentation of grape juice.

Canning of Grape Juice. As a result of experiments conducted by the author, Lyman Cash, and Ralph Celmer in 1935 and 1936, the following information has been secured.

Juices, both white and red, in unlacquered tin cans soon lost their fresh flavor, aroma, and color and acquired a disagreeable "tinny" flavor. Juices in lacquered ordinary coke-tin cans attacked the plate rather rapidly, whereas those in double-lacquered (reenameled) Type L plate remained in good condition for more than a year without appreciable loss in vacuum and without perforation of the plate. Beer cans lined with "wax" and sealed with Crown caps proved satisfactory for both still and carbonated juices. Deaeration of the juice before canning improved keeping quality. Enzymic clarification with pectinol or with clarase was rapid and satisfactory. Fining with bentonite at 140 to 180°F. also gave excellent clarification. However, the juices need not be fined or otherwise cleared; they may

be canned in the natural cloudy state. A blend of Muscat and Petite Sirah, or Muscat and Zinfandel, juices was satisfactory, but not so desirable as Pierce Isabella juice or a blend of this juice with a red Vinifera variety. Muscat juice, canned as such as a white juice, was very pleasing in quality and should have commercial possibilities. Acidification of Vinifera juice to about 0.85 gram total acidity per 100 cc. was found desirable.

The following procedure is suggested for red Vinifera juice: Pick Muscat grapes at about 22 to 23° Balling. Crush and press. Pick a red-juice variety, such as Petite Sirah, Alicante Bouschet, Zinfandel, or Carignane, grown in a coastal county at 19 to 20° Balling. Crush and stem. Heat at 160°F. for 5 min. Press hot. Cool at once. Mix equal volumes of the two juices. Deaerate by treating under 27- to 29-in. vacuum at 80 to 100°F. for 20 to 30 min. Flash pasteurize at 180°F. and cool to below 120°F. Add the amount of a 5 per cent water suspension of bentonite found best by small-scale trial. Mix well. Acidify with citric acid to 0.85 per cent total acid. Let settle several hours. Rack and filter. Heat to 140°F. Fill reenameled Type L cans with the hot juice. Seal in vacuum. Process at 160°F. for 20 min. Cool thoroughly.

For white Muscat juice proceed essentially as above, omitting addition of red juice.

For Pierce Isabella, Concord, or other red Labrusca or red Muscadine juice, proceed as directed above except that no Muscat juice is added. Or Concord juice prepared as previously described, including detartration, is flash-pasteurized to about 185°F., canned at or above 170°F., sealed, held several minutes, and then cooled. Reenameled, corrosion-resistant tin plate should be used.

An alternative procedure for the canning of grape juice is as follows. Extract the juices as previously directed. Flash pasteurize to 175°F., and cool to 80 to 60°F. Add a pectic enzyme in amount found by small-scale trial to be best (usually about 1:1,000). Let stand until clearing occurs. Rack. Filter. Heat to 185°F. Can hot at 175 to 180°F. in reenameled Type L cans. Cool thoroughly.

Carbonating Grape Juice. Grape juice can be carbonated in any of the standard types of carbonating machines. At the University of California the juice was placed in a heavy steel cylinder lined with "glass enamel" and was agitated mechanically at 32 to 36°F. in the presence of carbon dioxide gas under 20 to 30 lb. pressure. Thirty pounds pressure gives an agreeable degree of carbonating at 36°F.

The juice can also be carbonated by allowing it to flow downward against a stream of carbon dioxide in a narrow tube filled with glass beads, or by chilling the juice to 28 to 32°F. and passing a slow stream of carbon dioxide through it.

Juice carbonated at 30 lb. or greater pressure at room temperature can

be pasteurized at 140 to 150°F. without danger of subsequent molding, whereas noncarbonated juice must be pasteurized at 175°F. The lower temperature of pasteurization of carbonated juice results in much less injury to flavor and color than occurs at 175°F. or above. The carbonated juice may also be canned in beer cans and pasteurized 30 min. at 140°F.

Another method of preparing carbonated beverages consists in concentrating the juice to a sirup, followed by mixing the sirup and carbonated water in the bottle with standard soda-water-bottling equipment, followed by pasteurization at 145 to 150°F.

Alcohol in Unfermented Grape Juice. Hartmann and Tolman found by the analysis of 104 samples of Concord juice that 44 per cent of the samples contained less than 0.1 per cent of alcohol; 77 per cent contained 0.2 per cent or less; and 90 per cent showed 0.4 per cent or less by volume. The remaining 10 per cent contained from 0.4 to 1.07 per cent alcohol by volume.

They found that freshly picked grapes contained very little alcohol and that most of the alcohol was formed by yeast during transportation, storage before crushing, and crushing and pressing.

APPLE JUICE

Unfermented apple juice (sweet cider) is one of the most popular fruit juices sold in the United States. Much of this juice is consumed fresh, directly after pressing, or from barrels in which it is preserved with benzoate of soda. Benzoated cider is often of very poor quality, and usually the flavor of benzoate is evident. The sale of juice preserved in this manner is, in the author's estimation, the principal obstacle to expansion of the sweet-cider industry.

Varieties of Apples for Juice. Apple juice should possess a rich apple flavor and should be tart. The Winesap, Gravenstein, Roxbury, McIntosh, Jonathan, Spitzenberg, and Northern Spy are examples of good cider apples obtainable in commercial quantities.

Gore has compared the quality of juices from a number of leading apple varieties after pasteurization and storage. He concluded that apple juice to be most palatable to the average consumer should contain about 12 per cent or more of total solids and 0.5 per cent or more of total acid (as malic). Caldwell (1922), Brown (1936), Marshall (1947), and Atkinson and Strachan (1949) have compared many varieties for juice production.

Experiments by R. Celmer and the author in 1936 showed that, of Californian commercial varieties, the Gravenstein gave the most palatable canned juice. It was distinctly superior to the Newton Pippin.[1] Winesap

[1] Also commonly known as Newtown Pippin.

and Spitzenberg apples from Washington state and Stayman from Pennsylvania gave excellent canned and bottled juices. The apples from the Pacific Northwest are high in total acidity, i.e., tart in taste, which is a desirable characteristic.

In addition to the proper proportions and concentrations of acid and sugar, the juice must possess a distinctive and agreeable flavor. For example, the Ben Davis, while conforming in composition to Gore's requirements, yielded a juice of poor flavor and quality, because of its lack of distinctive apple flavor. The Yellow Newtown, Winesap, Northern Spy, Baldwin, Roxbury, and Kentucky Red all gave satisfactory juices.

Preparation for Crushing. Although apple juice is sometimes considered a by-product and a means of utilizing culls, the raw material should be sound, free from rot, worms, and fermentation. Apples to be used for juice should in all cases be thoroughly washed before crushing, because even under the best conditions they will carry considerable dust and are frequently contaminated with juice or pulp from spoiled fruit. The apples may be soaked by conveying them through a long tank of running water, and the loosened dirt may be effectively removed by sprays. Undoubtedly a rotary tomato washer would be ideal for the washing of apples. Merely washing the apples in running water a short time, as is done in some factories, does not cleanse them effectively.

Sorting is even more important than washing to make sure that rotten and wormy fruit is removed.

The Federal food and drug regulations prohibit the marketing of apple juice or any other food containing more than 0.018 grain of lead or 0.01 grain of arsenic as the trioxide per pound. Tolerances for some of the more modern insecticides are even lower, in some cases zero tolerance.

Robinson, of Oregon Agricultural College, who has studied this problem extensively, recommends immersion and agitation of the apples in an approximately 1.5 per cent hydrochloric acid solution, followed by rinsing in water to remove lead arsenate. Apple juice should be analyzed for lead and arsenic content to ensure its compliance with the law (for further details see *Oregon Agricultural Experiment Station Bulletin* 341). DDT-spray residue is now also a problem, although in California it is reported that by the time the apples reach the factory they are free of the insecticide. One producer stated that it decomposes before the fruit is picked. He also stated that lead arsenate is no longer used in his district, having been replaced by DDT. Therefore thorough washing in water to remove dust, etc., is all that is required, according to this grower. TEPP also disintegrates, usually within 48 hr., after application on the fruit, However, the producer should make certain that his juices do not exceed the Federal residue tolerances. Full information on this subject can be had from the Food and Drug Administration, Washington, D.C.

Grating and Pressing. The construction and operation of apple hammer mills, graters, and presses have been discussed earlier in this chapter.

Apple tissue is firm and tough, and the cells possess heavy walls; consequently crushing or grating and pressing must be thorough in order to obtain a high yield of juice. Crushing too finely, however, causes the pulp to be too soft to press without danger of bursting the press cloths. Pieces $\frac{1}{4}$ to $\frac{1}{8}$ in. thick are satisfactory. If the pieces are too large, the yield of juice will be low. The rack-and-cloth rather than the basket press is best for apples because of the pulpy nature of the fruit. The usual pressure applied to a press using racks 55 in. square is about 235 tons, or about 150 lb. per sq. in.

The yield of juice from one pressing should be 170 gal. or more per ton. The pomace (press cake) may be broken up in a pomace picker (similar to an apple-grating machine) and pressed a second time, but the second pressing of juice is of very dark color and of poorer flavor than the first pressing; it is more suitable for vinegar than for sweet cider.

Clearing by Filtration of Fresh Juice. In some plants the fresh juice is filtered without previous enzyme treatment. One procedure consists in straining the juice to remove coarse particles, chilling by passing the juice through a plate-type heat interchanger cooled by circulating ice-cold water, storing overnight in tanks, drawing off the settled juice, and filtering it. The usual filtration procedure consists in first mixing water or some of the juice with filter aid to give a thin slurry which is pumped through the filter press or other suitable filter to precoat the filtering surface. Then, as the main body of the juice is being filtered, a small amount of filter aid is added continuously before it reaches the filter in order to maintain a fresh surface and prevent clogging of the filter by apple colloids. The resulting juice is brilliantly clear. The usual method of preservation consists in flash heating to 185 to 190°F., bottling or canning at above 175°F., holding a short time to sterilize container and closure, and cooling with water. In one plant quart-size and smaller bottles are cooled by sprays of cold water in a walking-beam conveyer-type enclosed cooler, and gallon bottles are cooled in the same manner with tempered water (warm at first and then progressively cooled). Bottled samples of juice prepared in this manner have been held for more than 2 years in the author's laboratory without formation of a cloud or sediment.

Use of Pectic Enzymes. Most of the bottled apple juice produced in the United States is clarified with a commercial pectic enzyme such as those made by Rohm and Haas of Philadelphia and the Takamaine Laboratories of New York. Pectinol A of Rohm and Haas is widely used for this purpose.

The enzyme is furnished by the manufacturer as a mixture of dextrose sugar and dry enzyme with the dextrose as a carrier for the enzyme. The preparation contains a small amount of gelatin.

The required amount of the enzyme preparation is added to the freshly expressed juice in tanks of medium size, commonly of 1,000 to 1,500 gal. capacity. It is mixed very thoroughly with the juice, one method being to dissolve it in several gallons of juice and add this solution to the juice as the the tank is being filled. Usually the juice is at room temperature, which in the fall and winter in some localities may be rather low. The lower the temperature the slower is the action of the enzyme and the greater the amount of enzyme required. Activity is most rapid at 100°F., according to to Rohm and Haas Co. In California plants it is customary to allow the enzyme to act overnight. The juice is then drawn off, mixed with infusorial-earth filter aid, and filtered, usually in a plate-and-frame filter.

The suggested ratios of time, temperature, and amounts of Pectinol A required are given as follows by the manufacturer:

OUNCES OF PECTINOL A REQUIRED PER 100 GAL. OF JUICE

Temperature, °F.	Period of treatment			
	5 hr.	15 hr.	30 hr.	48 hr.
40	——	30 oz.	15 oz.	10 oz.
60	54 oz.	18 oz.	9 oz.	6 oz.
100	14 oz.	5 oz.		

SOURCE: Rohm and Haas.

However, juice producers find that it is advisable to determine by small-scale tests the best concentration of enzyme for their conditions of temperature and variety of apple.

Marshall has pointed out that occasionally enzyme-treated juice may form a deposit in the bottle or can on prolonged storage in the container. He has recommended that 5 to 10 oz. of nonacidified, starch-free liquid apple pectin of 50 grade be added and thoroughly mixed with each 100 gal. of juice before pasteurizing and bottling. In cans the sediment is not very noticeable since it adheres to the container to a considerable extent. Pasteurization should be high enough to inactivate the enzyme. Such treatment will arrest its action on pectin and other colloids and any tendency to cause darkening of the color after bottling. California producers who were consulted on this question report that they have not encountered the sedimentation observed by Marshall, although one producer has reported the formation of small cottony particles in bottled enzyme-treated juice.

Use of Ascorbic Acid. Pederson in 1947 conducted experiments upon the effect on color and general quality of apple juice of adding a small amount of ascorbic acid to the apples at the crusher. It was sprayed on the apples as they entered the crusher or was added to the crushed apples immediately after crushing. In 1948 the experiments were continued by Holgate, Moyer,

and Pederson. The ascorbic acid was applied as a solution in apple juice. It was found that 6 grams of the acid per bushel (40 to 45 lb.) of apples was sufficient to protect the juice for at least 2 hr. between deaeration and pasteurization and leave 20 to 25 mg. of ascorbic acid per 100 cc. in the finished juice. The juice is deaerated and then flash-pasteurized as soon as possible after deaeration. Pederson recommends that the bottles be filled full at 165 to 175°F. After holding long enough to sterilize the caps, the bottles are cooled quickly in water. The juice made in this manner is not clear, as it has not been filtered or enzyme-treated. The juice has a light, attractive color and much of the flavor of fresh apples.

Atkinson and Strachan (1949) in Summerland, British Columbia, have also conducted experiments on the addition of ascorbic acid to the juice and the fruit at the hammer mill. The juice is strained to remove coarse particles, pasteurized, filled hot into cans or bottles, and cooled. The author has sampled commercially canned juice made in British Columbia by this method and found it excellent in flavor and appearance. It was slightly cloudy. The flavor and aroma were those of the fresh fruit.

Ascorbic acid is a strong reducing agent, a fact that accounts for its action in preventing oxidation and darkening of the juice. If so desired, enough of the ascorbic acid (vitamin C) can be added to bring the level to that of orange juice, 40 to 50 mg. per 100 cc.

Packaging and Pasteurization. Until fairly recently most fruit juice, including apple, was pasteurized in the bottle or can after filling cold and sealing. Large shallow wooden vats equipped with slat false bottoms were used. The bottles were placed, preferably on their sides, in the vat, and water was added to cover and heated to 175 to 180°F. for a long enough time to prevent subsequent spoilage by mold. The containers were then cooled in the pasteurizing vat with water. An improvement consisted in pasteurizing the filled and sealed bottles or cans in a continuous pasteurizer consisting of a long vat filled with water heated by direct steam, the temperature becoming progressively higher as the bottles or cans were conveyed through the vat; or they were heated by sprays of water, at first moderately hot and then progressively hotter. In one type of pasteurizer the cans are rolled through sprays of water near the boiling point, the rolling serving to agitate the juice and greatly hasten heat penetration.

At present, however, the juice is usually heated in a plate-type heat interchanger to 185 to 190°F., filled into bottles or cans at or above 175°F., sealed, held a short time, and then water-cooled.

In some plants the caps are sterilized by passing the filled and capped bottles through sprays of hot water at 190°F. and the bottles then cooled under water sprays.

Distribution under Cold Storage. In experiments made at the University of California, unpasteurized cider in sealed cans retained the qualities of

the fresh juice for more than 24 months when stored at 0 to 15°F. At 32°F. fermentation occurred. When stored in open containers at 0 to 15°F., the juice acquired a disagreeable musty flavor, caused by the absorption of odors from the atmosphere of the cold room; paraffined milk bottles and Lily Tulip cups proved satisfactory.

The Boehi, or Seitz-Boehi, Process. This method of clearing, storage, and bottling of apple juice was devised by Professor Boehi (or Boehe) in Switzerland and later called the Seitz-Boehi process, since Seitz filters are generally used and the Seitz Co. cooperated closely in the commercial development of the process. The author observed it in use in Switzerland, England, and Holland. Properly used it gives excellent results. Briefly, it consists of the following steps. The fresh juice is treated with a pectic enzyme, filtered and then germproof-filtered through a Seitz filter equipped with sterile, tight-filtering pads, deaerated to remove practically all disolved air and oxygen, chilled, impregnated to about 100 lb. per sq. in. pressure with carbon dioxide, filled under CO_2 pressure into glass-lined or other specially lined tanks previously filled with CO_2 gas, and stored in a room refrigerated to around 32°F. As needed for bottling, the juice is drawn off as nearly aseptically as possible and is again germproof-filtered in a "sterile" room into sterile bottles, and these are closed with sterile closures.

The author was told that the oxygen content of the juice must be reduced almost to zero in order to prevent growth of yeast and lactic bacteria. No pasteurization or other heat treatment is given at any stage of the process. The juice is light amber in color and possesses much of the fresh flavor of the apples. However, it also has a somewhat different flavor from that of freshly pressed juice. The process has not been used extensively in the United States.

Carbonating. Apple juice is greatly improved for the average consumer by carbonating, and some of the bottled juice now on the market is lightly carbonated, i.e., at 15 to 20 lb. pressure per sq. in.

During the Prohibition era some breweries were converted into juice factories in some apple-producing localities, particularly in the Pacific Northwest, and the carbonating, bottling, and pasteurizing equipment formerly used in these establishments for beer was used successfully for cider.

The Schwartz Process. The well-known S and W Co. of Redwood City, California, bottles and cans a cloudy apple juice of remarkably fresh flavor and light (almost white) color. The washed and sorted apples are "juiced" in a Schwartz hammer-mill-type juice extractor under vacuum. The juice is further vacuumized, flash-pasteurized, canned or bottled hot, and cooled. Or the operations are conducted in an atmosphere of inert gas such as CO_2 or N_2. This product, advertised as comminuted apple juice, has become popular.

LOGANBERRY JUICE

The preparation of loganberry juice was once an important industry of the Pacific Northwest, where most of the juice was then canned.

When the berries are fully mature and have attained their maximum color and sugar content, they are gathered in shallow trays. The fruit is soft and develops fermentation quickly after harvesting, and for this reason it must be crushed within a few hours.

Juice Extraction. Various methods of extracting the juice can be used, but the following is recommended. The berries are crushed in a stainless-steel crusher, heated, and pressed in a rack-and-cloth cider press. In most cases the berries are heated to 160°F. before pressing to increase the yield and to obtain a juice of more intense color. Juice from unheated fruit contains less pectin and is therefore more easily filtered.

If the berries have not been heated before pressing, the juice is heated after pressing, to pasteurize it and to coagulate heat-precipitable proteins. Stainless-steel or glass-lined equipment should be used in heating berries and berry juices. Most other metals, including tin, injure the color.

Filtration. Filter presses or pulp filters may be used for filtering the juice. Because of its high content of gums and pectin, it is difficult to filter. Addition of infusorial filter aid is advisable.

It is not necessary to place the juice in cold storage to permit settling before filtration. It is feasible to filter the juice satisfactorily after 24 hr. settling at room temperature following preliminary pasteurization at 160 to 165°F. to coagulate proteins. Clarification with a pectic enzyme greatly aids filtration.

Addition of Sugar. Unsweetened loganberry juice, after bottling or canning and pasteurizing, usually develops a disagreeable astringent flavor and loses most of its color, but the addition of a moderate amount of sugar prevents these undesirable changes. It is made to about 36° Brix and is diluted with an equal volume of water for serving. The added sugar gives a more pleasing beverage than the unsweetened juice, but sugar in excess of 50 per cent often causes the juice to form a jelly unless treated with a pectic enzyme.

The sweetened filtered juice can be canned or bottled and pasteurized as described for other juices. Before canning it is usually diluted with an equal volume of water and sweetened to taste (about 12 to 14° Balling) with sugar. Reenameled Type L cans are used.

The yield of freshly pressed juice is 160 to 180 gal. per ton, and twice these amounts of diluted juice. The juice may be pasteurized into the cans at 175 to 180°F. or pasteurized in the cans.

Carbonating. An excellent carbonated beverage for bottling purposes can be made from sweetened loganberry juice. One and one-half ounces of

sweetened juice of 50° Balling is added to 8-oz. soda-water bottles. Carbonated water at 30 to 50 lb. pressure is added to fill the bottle, which is then Crown-capped and pasteurized at 150°F. for 30 min.

OTHER BERRY JUICES

Other berries also yield palatable beverages, particularly if sweetened and diluted with carbonated water.

Blackberry Juice. Blackberry juice can be prepared as described for loganberry juice, but the Balling degree of the juice should be increased to 30 by the addition of cane sugar, to prevent deterioration of flavor and color. Unsweetened juice pasteurized and stored at room temperature loses most of its color and flavor. Because of its intense color it is very useful in fruit punches and sherbets.

Gore reports yields of 66.9 to 69.6 per cent of juice from unheated blackberries and 74.4 to 80.9 per cent from blackberries heated before pressing. The sweetened juice is diluted before serving.

Youngberry Juice. The youngberry, or Young blackberry, is grown in considerable quantity on the Pacific Coast. It is a large berry of pronounced flavor and moderate acidity and is popular as a dessert fruit. In experiments by R. Celmer at the University of California, a very pleasing canned diluted juice was prepared, as described for canned blackberry juice.

This berry is adaptable to culture not only in Oregon, California, and Washington but also in many sections of the Southern states. It could well become an important juice fruit.

Boysenberry Juice. This variety yields an excellent juice. It is best if sweetened to 35° Brix before bottling, to be diluted before serving.

Raspberry Juice. If acidified slightly with citric acid, raspberry juice of satisfactory quality may be prepared and canned or bottled as described for blackberry juice. It is lighter in color and of lower acidity than loganberry juice, but it is very rich in flavor and aroma.

CITRUS JUICES

Until about twenty years ago all attempts to pack commercially a satisfactory canned or bottled orange or lemon juice were unsuccessful because of undesirable changes in flavor and odor during storage. With development of the technique devised by Joslyn and Marsh of the University of California and others, and adoption of a special enamel, the canning of orange juice has become an important industry in Florida and California.

For a number of years the canning of grapefruit juice has been conducted commercially in Florida, Puerto Rico, and Texas.

Canning of Orange Juice. In California the Valencia orange is much superior to the Navel for juice purposes, because the Navel juice turns bitter soon after extraction.

Fruit to be used for juice production should be orchard run, freshly picked, and should not consist of packing-house culls that have stood too long in a packing shed. The latter fruit is apt to give juice of poor flavor

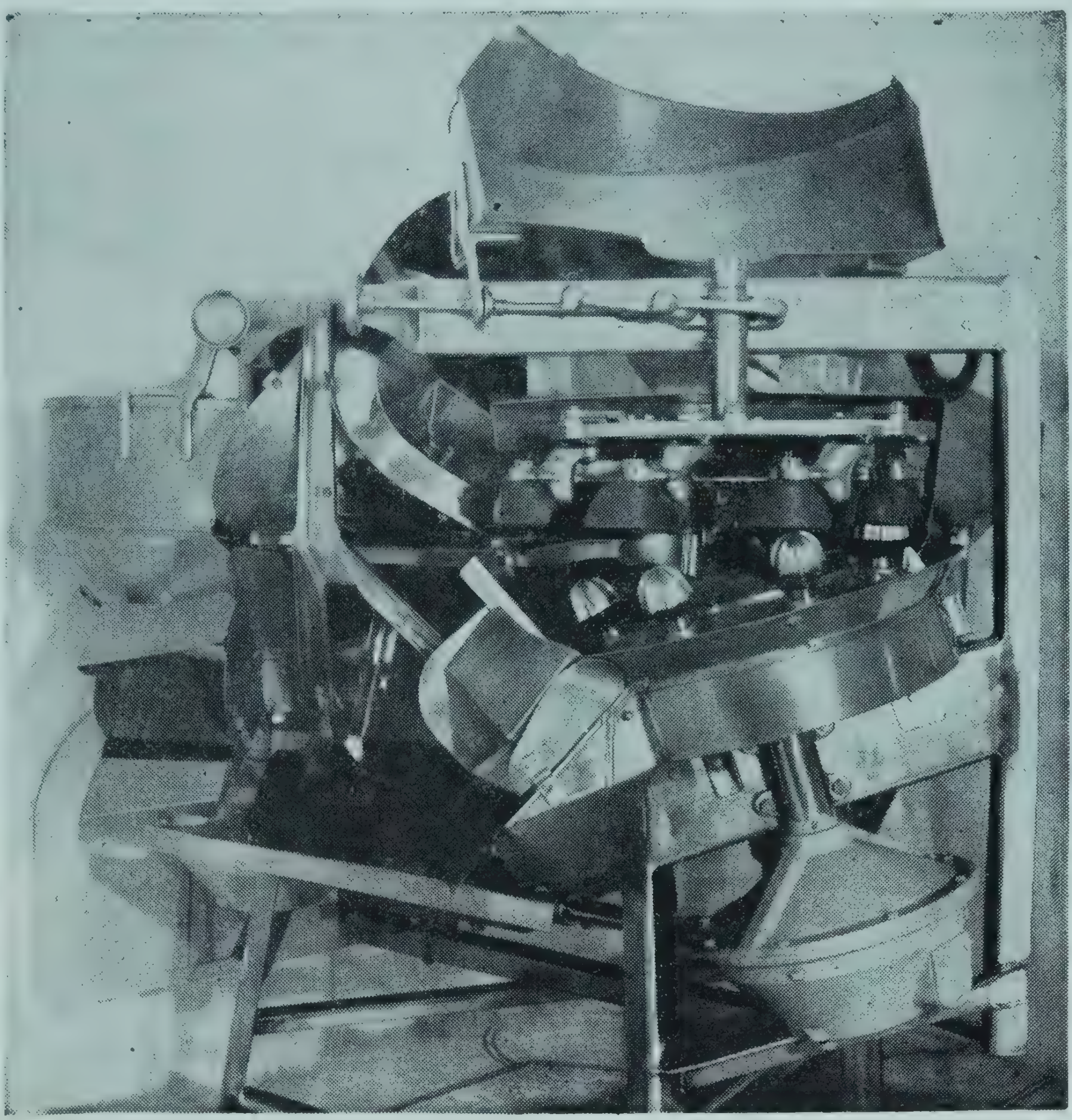


FIG. 64. Brown citrus-juice extractor. (*Food Industries.*)

and aroma. The fruit should also be well ripened. In most plants the oranges are delivered in bulk by truck and are stored in ventilated slat-bottomed bins. Both practices result in some damage to the fruit, particularly if it is allowed to stand in the bins several days before use. Best quality is obtained by using the fruit as soon as delivered and with as little rough handling as possible en route from the grove.

In the average juice plant in California the fruit is first sorted on a belt to remove rots and other unfit oranges. It then passes through a "soak" tank of water or detergent and water, then to a brush washer, where rapidly revolving brushes and sprays wash the oranges very vigorously and thoroughly. A strong antiseptic solution may be used in the soak tank preceding the brush washing to reduce the numbers of microorganisms, but

this is more apt to be done when the juice is to be frozen. The brush-washed fruit is again sorted and then graded for size so that each juice-extracting machine will operate on fruit of fairly uniform size. The oranges are cut in half by circular knives automatically and are then reamed automatically on Brown, FMC, or other juice extractors that give a pulpy juice. The Brown extractor operates on the same principle as the familiar hand reamer (Figure 64). Another widely used citrus-juice extractor is the FMC "super-juicer" described as follows by its manufacturer, the Food Machinery Corporation:

> Extractor cups are provided with 20 fingers each and consist of upper and lower cup halves so designed that their fingers interlock. After the fruit enters the lower cup the two halves close and progressively apply pressure to the fruit. The lower cup has a circular cutter projecting upward from its base which cuts a small plug from the fruit. As the pressure on the fruit increases, juice is forced out through the cutter tube into the juice trough. During squeezing operations the peel oil is pressed from the rind by the pinching action of the fingers and flows into the oil collector trough. The pressure of the fruit against the outer wall of the cutter tube prevents mingling of the juice and the oil. After extraction the hull is ejected into a refuse conveyor and the juice flows into a conventional type mesh screen finisher for the removal of plugs, heavy pulp, etc.

The oil is recovered as a by-product; the peels are collected and dehydrated for use as stock feed (Figure 65).

The rotary juice extractor used extensively in Florida and Texas consists of two upper rolls containing depressions or cups and two lower rolls equipped with projections that fit into the cups as the two sets of rolls revolve. The fruit is cut in half automatically; as the drum revolves the halves are carried in the cups until the projections on the lower drum meet them, and as the drums revolve toward each other, juice is expressed from the halved fruit. The fruit is size-graded by machine before going to the rotary juicers.

The Citro-Mat juice extractor is also of the drum type. It will take fruit of all sizes. First the fruit is cut in half by a circular, revolving blade. The halves are pressed between the revolving front drum and a grid plate. Juice and fleshy pulp are squeezed out and fall into a trough beneath the grid. The machine separates seeds, cell-wall material, and membranes from the juice. According to the manufacturer, Bireley's Division of General Foods Corp., the juice can be removed at preselected points in the process to control the amount of oil in the juice. A rear drum, the surface of which carries numerous projecting pins about ½ in. long, revolves approximately twice as fast as the front drum. The front-drum surface has short pins that carry the halved fruit against and past the grid. A shaving device is sometimes attached to slice off a thin layer of the yellow oil-containing outer

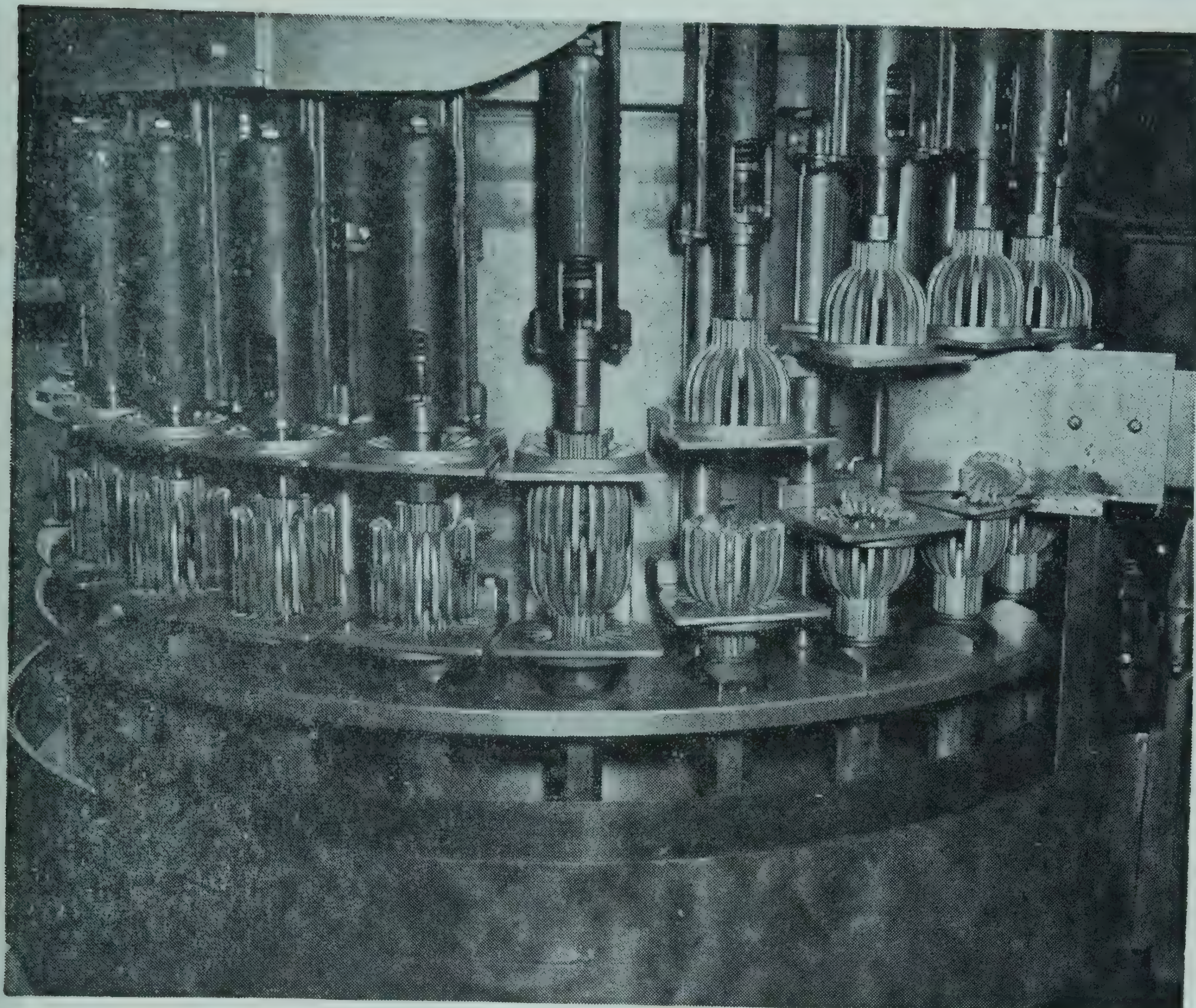


FIG. 65. FMC citrus-juice extractor. (*Food Machinery Corp.*)

rind or skin. Oil may be recovered from these shavings by pressing. The juice, in any extraction method, is next sieved, usually by a tomato-finisher type of machine, to give a fine-grained cloudy juice, and centrifuged to remove oil. It is next deaerated under high vacuum in a stainless-steel chamber through which the juice travels in a thin layer or film or into which it is sprayed. It is pumped from the deaerator into the can-filling machine. The cans are filled, and just before sealing the air in the head space is swept out with steam or inert gas. It is sealed in the usual double-seaming operation. The sealed cans are flash-heated quickly in a pasteurizer, where they are vigorously rotated or agitated and are thus heated extremely rapidly. They are heated to about 195°F. and are then rapidly cooled under sprays of cold water with vigorous agitation.

The foregoing is one method of canning the juice. In another method the juice is flash-heated to about 190 to 195°F. after deaerating and is cooled and canned at about 175°F. In another, it is heated to a temperature above 212°F. in a flash heater, for example, to 240°F., for a very brief interval, then cooled to canning temperature, about 175°F., canned hot, sealed, and cooled.

The purpose of heating the juice in the can to about 195°F. or in the flash pasteurizer to 190 to 240°F. is to inactivate pectic enzymes, particularly the enzyme responsible for curdling of the juice after canning. It is perfectly feasible to preserve orange juice by pasteurization to 150°F., but juice heated to such temperature would show curdling (coarse granulation) after canning and standing a few weeks. The purpose of sweeping air out of the head space of the can is to remove oxygen that would later damage the flavor.

In Florida, according to G. L. Marsh,[1] one commercial procedure was about as follows in 1945: The fruit was washed, then heated 1 or 2 min. in water to wilt the skin. Next the juice was extracted on rotary or Polk extractors, which gave juices containing considerable essential oil from the skins. The juice was next strained and transferred to surge tanks, where it it was blended and standardized. It was next deoiled in a vacuum deoiler in which the juice boiled momentarily, losing most of the essential oil. It was then flash-heated to 195 to 205°F., filled into cans at or above 175°F., sealed, inverted for a few seconds to sterilize the lids, cooled in a water-spray cooling unit, transported by conveyer while still warm to dry the surface of the cans, labeled, and cased (see also Heid, 1945).

The methods described in the foregoing paragraphs are generalized and probably do not fit exactly the procedure used in any one plant in either California or Florida.

In California enamel-lined cans ("citrus enamel") are used, in order to protect the flavor. In Florida plain tin cans are generally used, as they appear to provide adequate protection for the Florida juice.

The flash-heated juice may be filled into bottles, instead of cans, at 180 to 185°F., sealed, and cooled quickly with tempered sprays of water.

Oil. In order to meet the requirements for U.S. Grade A, or Fancy, orange juice, the content of essential oil must not exceed 0.03 per cent by volume. Juice extracted in the Brown and FMC machines usually meets this requirement, according to producers. Surplus oil can be removed by heating the juice under high vacuum to about 125°F. The vaporized oil and water vapor can be recovered by condenser.

Storage. Orange juice in cans or bottles held at room temperature deteriorates rather rapidly in flavor and aroma. Therefore it is now customary in California to store the canned juice in cold storage until it is to be shipped to the retail trade. It retains its flavor for several months with very little deterioration at 30 to 40°F. Because of the perishability of the flavor of canned citrus juices, the retailer should be supplied frequently with small deliveries of juice rather than infrequently with large deliveries.

Orange Beverage Bases. Lightly sweetened orange juice is concentrated *in vacuo* in stainless-steel vacuum pans to a heavy sirup for use as a base

[1] Private communication.

for carbonated and still beverages. One such still beverage was formerly distributed extensively in milk bottles for sale in soda fountains and for use in the home. It is made by diluting the sweetened concentrate to drinking strength. Carbonated bottled beverages made from such concentrates are also popular. The sirups and the carbonated beverages are preserved with sodium benzoate. Similar beverages, but carbonated, are preserved by pasteurization.

Frozen Orange Juice. Some orange juice is preserved by freezing in enamel-lined cans for use by ice-cream producers, hospitals, steamships, and other large users of fruit juices. Attempts to distribute frozen orange juice in the retail trade or direct to the home have not been very successful, although the product is satisfactory. Apparently housewives prefer to use the fresh oranges or the canned juice, as the cost for an equivalent amount of juice is considerably less than that of the juice distributed in the frozen state. Some frozen orange juice in special paperboard cartons was once marketed. For further discussion of frozen juices see Chapter 25.

Lemon Juice. Lemon juice deteriorates in flavor even more rapidly than orange juice. Nevertheless, there is at present a moderate demand for canned lemon juice prepared and canned by the procedure described for the canning of orange juice. Within a few weeks after canning the lemon juice develops a "terpeney," or stale lemon, taste and odor; yet it is satisfactory for use in mixed drinks and appears to find sale to bars, restaurants, clubs, etc.

Some lemon juice is bottled also. It may be prepared by reaming the fruit, screening out seeds and coarse pulp, vacuumizing to remove oxygen, flash pasteurizing at 195 to 205°F., bottling at 175°F., sealing hot, and cooling. Or it may be cooled after flash pasteurizing, bottled warm, sealed, and pasteurized in the bottle at 165°F. Filling at 175°F. is preferable, as air is excluded at this temperature. Frozen juice and lemonade sirup have become popular (Chapter 25).

Lime Juice. Lime juice, like lemon juice, rapidly develops a "stale" taste after bottling or canning, although this off flavor is much less objectionable in lime than in lemon juice. Considerable lime juice is filtered brilliantly clear and preserved in bottles with sulfur dioxide.

It possesses a richer flavor, however, if bottled in the cloudy condition. The procedure outlined above for lemon juice may be used successfully.

Grapefruit Juice. The canning of grapefruit juice has been a well-established industry for a number of years. Most of the commercial product is packed in cans. Those lined with citrus enamel should be used in order to minimize development of a tinny flavor, although practically all grapefruit juice is packed in plain tin cans at present. In the early days of the industry considerable loss was encountered from hydrogen swelling by reaction of the acid of the juice with the tin plate. With improvement in

tin plate and in preparation of the juice, such losses are now relatively slight.

The juice is canned either in its natural state or slightly sweetened with cane sugar, depending upon the composition of the fruit used.

In experiments made at the University of California Food Technology Department laboratory, it has been found that fresh flavor and aroma are retained in greater degree if the procedure outlined for the canning of orange juice is used instead of canning without vacuumizing or flash pasteurizing.

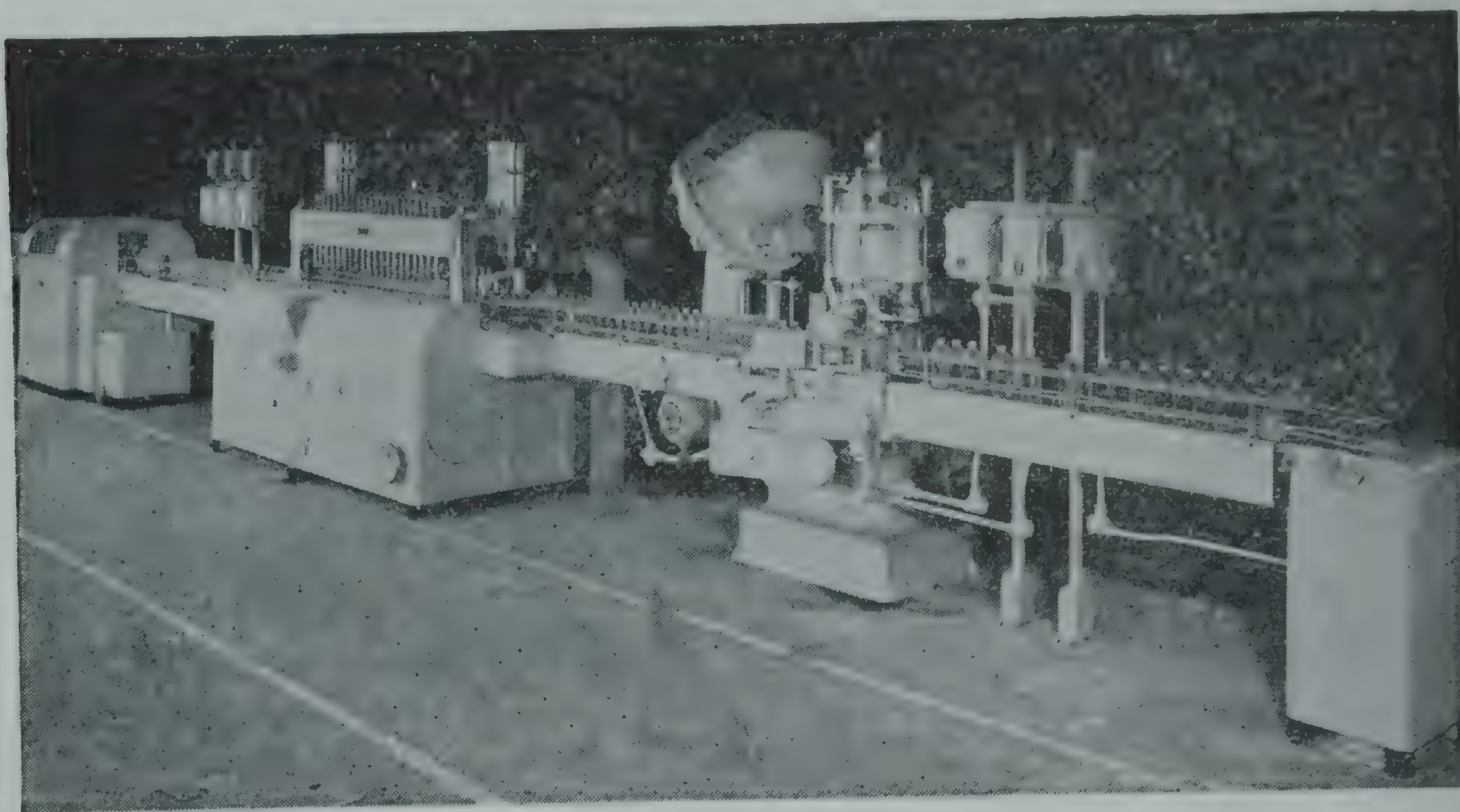


Fig. 66. Automatic bottling assembly with air cleaner, straight-line vacuum filler, and four-head rotary capper. (*Pneumatic Scale Corp.*)

The recommended procedure for California fruit, then, is briefly as follows: Use well-ripened sweet fruit. Cut in half. Remove juice by reaming, avoiding expressing essential oil from the rinds. Strain. Treat under a high vacuum (27 to 29 in.) to remove dissolved and occluded oxygen or use continuous vacuumizer. Flash pasteurize at 195 to 205°F. for about 1 to 2 min. Cool to 175°F. Can at this temperature in citrus-enameled cans. Seal hot. Invert for about 3 min. to sterilize lids. Cool thoroughly under sprays of water as described for orange juice.

It is recognized that grapefruit juice is much more stable in flavor than orange, lemon, and lime juices. Consequently it withstands more severe treatment and retains its flavor more satisfactorily after canning or bottling. Hence at present much grapefruit juice is not deaerated. Like canned orange juice it should be stored at 30° to 36°F. if it is to be held several months before marketing.

Bottling may be conducted as previously described for orange juice.

Pineapple Juice. Canned pineapple juice is now third to canned tomato juice and orange juice in respect to volume of pack, the 1956 pack of this

juice being 14,500,000 cases, according to *Western Canner and Packer*. It is an excellent juice for canning, since it retains its fresh flavor and aroma remarkably well and is of such acidity and sugar content that it is properly balanced in flavor for use as a breakfast beverage.

The principal raw materials from which pineapple juice is prepared, according to Mehrlich, are the shredded meat obtained from the inner portion of the peels left after peeling of the pineapple by the Ginaca machine (see section in chapter on fruit canning), the small pineapple that is too small for canning in the usual form, the trimmed cores from the Ginaca machine, and the juice that is drained from the crushed pineapple and obtained by draining at various other steps in pineapple canning. A machine called an eradicator removes the meat adhering to the peel and delivers it in shredded form, usually in two forms, viz. that in the outer layer layer for use in canned shredded pineapple and that nearer the peel for use in making juice. The very small fruit is peeled in a Ginaca machine if it is to be used for juice. The cores from fruit prepared for canning are trimmed and used for juice extraction. They and the peeled, small pineapple are shredded, and the juice extracted in one of several different types of juice extractors.

In the Schwartz extractor a very powerful vertical member revolves against a serrated surface, and the juice and pulp are separated by a fine screen. An extractor consisting of a powerful screw revolving inside a stainless-steel screen and similar in design to the well-known screw-press-type juicer used for extracting juice from tomatoes has also been used for extracting juice from the shredded pineapple. The FMC Model 76 drum-type juice extractor is described by the manufacturer about as follows: It differs from screw-type extractors in that a special elliptical drum rotor is used in place of the conventional screw rotor. The shredded juice stock is forced into the juice-extracting section by a double spiral screw. The elliptical drum kneads the juice stock against a screen, thus extracting the juice as the stock moves toward the outlet of the extractor. An adjustable back-pressure plate at the discharge end controls the degree of extraction.

The juice from the various sources is combined and well mixed. It is then heated in a continuous pasteurizer such as is used for other juices and is screened to remove coarse particles of meat that have gotten by the extractor. It is then run through a high-speed centrifuge, such as a Sharples or De Laval continuous centrifuge, which removes all the coarser suspended material but leaves the very finely divided cell fragments to impart a slight cloud or haziness to the juice. The juice may or may not be homogenized in equipment similar to that used in the homogenizing of milk or ice-cream mix, in order to give the suspended material greater stability by breaking it up into very fine fragments.

The juice is preserved by either flash pasteurization and canning hot or

by pasteurization in the can. In the former procedure the blended juice is heated to approximately 195°F. in a continuous heat interchanger such as an APV plate-type pasteurizer, canned in plain tin cans directly from the pasteurizer, held hot several minutes to sterilize cans and can ends, and then rapidly cooled in water. In the second method the juice is canned after the centrifuging and blending described above, steam-flow- or vacuum-sealed or filled at a high enough temperature to give a good vacuum after canning, and is then processed in a continuous agitating sterilizer such as is used for canned pineapple, being heated long enough to bring the temperature of the juice to about 195°F. The cans are then rapidly water-cooled.

To a certain degree the production of canned pineapple juice may be considered a by-product operation since the raw materials are largely the by-products of pineapple canning. The fruit is grown primarily for canning as sliced pineapple rather than as juice. On the other hand, only raw material of sound and very good quality is used. Recently a blend of pineapple and grapefruit juices has been canned commercially by the California Packing Corporation. The product is proving popular and is now also canned by The Dole Hawaiian Pineapple Company.

Tomato Juice. As tomato juice has become an important tomato product and as much of the equipment used for preparing other tomato products is also employed in producing tomato juice, the preparation and preservation of this juice are presented in Chapter 16.

Pomegranate Juice. This is a subtropical fruit found in California and Arizona. The rind contains a very large amount of excessively "puckery" tannin, which enters the juice and renders it undrinkable if the whole fruit is crushed and pressed in the manner employed with apples. If, however, the uncrushed whole fruit is placed in a basket press under moderate pressure, a juice of pleasing flavor and attractive purplish-red color is secured.

The juice is easily clarified by heating in a flash pasteurizer to 175 to 180°F., cooling at once, settling 24 hr., racking, and filtering. It may then be bottled and pasteurized as previously described for grape juice.

If the juice should have an excess of dissolved tannin, the tannin content should be determined by titration with potassium permanganate as directed in "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists," and before flash pasteurization there should be added sufficient 1 per cent gelatin solution to precipitate about two-thirds of the tannin. One part by weight of gelatin is roughly equivalent to one of tannin. A preliminary test with about 1,000 cc. of the juice should first be made, as addition of an excess of gelatin will cause the juice to become permanently cloudy and extremely difficult to filter.

Passion-fruit Juice. In Australia this fruit is produced in considerable quantity for preparation of juice. It grows on a vine similar to the hop vine

in growing habits, but of course not similar to it botanically. The fruit is cucumber-shaped and contains many seeds. By a combination of crushing, pressing, and screening, a cloudy juice may be obtained. It is very aromatic and very acid. Sugar should be added to bring the Balling to approximately 25°, as the juice is of exceptionally high acidity. The juice may then be canned or bottled and pasteurized in the usual manner at 140 to 150°F. in cans or at 175°F. in bottles. Sherman and associates of the College of Agriculture in Honolulu have improved the method of extracting the juice. It blends well with other juices of low acidity. It is very useful in preparing mixed fruit punches and mixed alcoholic drinks.

Apricot Nectar. This product has become rather popular. Its production was initiated as a result of experiments made by A. Shallah and the author at the University of California. The following procedure was used: The apricots (thoroughly ripe) were pitted, steamed until soft, sieved in an American Utensil Company tomato-juice machine, and mixed with an equal volume of 15° Brix sirup. The mixture was heated to 180 to 185°F., canned hot, sealed, processed at 212°F. for 20 min. in No. 1 Tall cans, and cooled. This procedure retains vitamin C, whereas cold sieving of the fresh raw fruit may lose it.

The present commercial procedure consists in washing, steaming the whole fruit, sieving to a purée, finishing, adding a dilute sucrose sirup of 13 to 15° Brix equal to volume of purée, heating, canning hot, sealing, and cooling. A hammer-mill-type disintegrator can be used with pitted fruit to make the purée. In most plants a tomato-pulp cyclone is used with the whole cooked, unpitted fruit.

In one large cannery the sorted and washed fruit is heated in an augur-type continuous cooker, pitted and puréed in a tomato pulper, sieved in a second pulper, or finisher, and blended with a sucrose sirup of about the same soluble-solids content as the purée. The blend is sieved by finisher, heated to about 180°F., canned, and sealed hot. It is then given a short process at 210 to 212°F. and cooled.

In another plant citric acid is added if the blend is found to be lower in acidity than is desired. The aim is to have the final nectar of about the same pH as that of the purée before addition of the sirup.

Peach and Pear Nectars. The fruit is pitted or cored and peeled. It is then steamed until soft, sieved, mixed with dilute sirup, and canned as described for apricot nectar.

Plum Nectar. Ripe plums are washed, steamed soft, pulped in a tomato cyclone, finished in a tomato finisher, mixed with 15° Brix sirup, and canned as above. Enamel-lined (berry enamel) Type L cans should be used for red plum juice. Or the plums may be heated with an equal weight of water until soft, pressed, roughly filtered, sweetened to 20° Brix, and canned or bottled.

Prune Juice. This is a water extract (infusion) of dried prunes. Leonard, Lane, Ponting, and the author found the following procedure to give an excellent juice. Dehydrated prunes of best quality were heated to 175 to 180°F. with about four times their weight of water for several hours. The resulting "juice" was placed on a second lot of prunes, and heating was repeated. Three such operations were made. Then the once-extracted prunes were extracted with water or dilute juice twice more. Thus each lot was extracted three times. The final juice was diluted to 20° Brix, heated to 185 to 200°F., canned hot in Type L cans, sealed, and cooled.

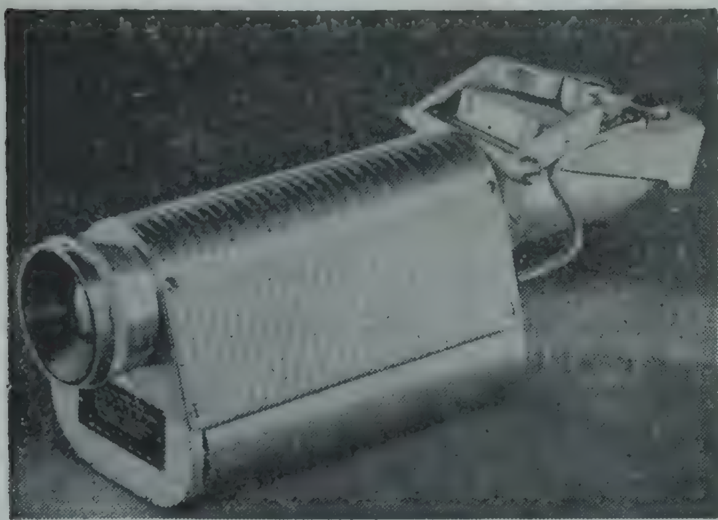


FIG. 67. Hand refractometer AO type. Useful in analysis of juices. (*American Optical Co.*)

Juice of fresh prunes was prepared experimentally by Cruess and Rivera, 1951. The sorted fresh fruit was washed, steamed until soft, and passed through a tomato pulper to remove pits and to give a coarse purée. The purée was cooled to 100°F., and 2 grams of Pectinol O was added per liter and mixed well with the purée. After standing overnight about 1½ per cent of infusorial-earth filter aid was added and the mixture was pressed in a rack-and-cloth apple-juice press. Without the enzyme treatment it is impossible to press the purée. The enzyme hydrolyzes the pectin, and as a result the viscosity of the purée is greatly reduced. The infusorial earth materially improves pressability. The juice was filtered, flash-pasteurized at 185°F., bottled in bottles heated in steam to bring them to the temperature of the juice, sealed, held a few minutes to sterilize caps, and cooled in water in the usual manner. The juice is deep red to purple red when made from prunes of the Italian (Fellenberg) variety and light red if made from the French variety (Petite Prune d'Agen.) The flavor is that of fresh prunes, the juice of the Italian variety being quite tart in taste and that of the French variety mild and subacid. Both juices are mildly laxative.

CARBONATED FRUIT BEVERAGES

Many of the so-called "fruit" soda waters on the market are prepared from artificially colored and flavored sirups. While many of these beverages are palatable, they contain in most instances little or no fruit juice. Investigations at the University of California have proved that fruit juices can be readily converted into sirups suitable for the use of soda-water bottlers and soda fountains and that the consuming public prefers these

beverages to those produced from the artificially colored and flavored sirups.

Preparation of the Sirups. A detailed discussion of the preparation of fruit sirups will be found in Chapter 13.

The juice is obtained from the fruit in the manner best suited to the fruit in question and as described earlier in the present chapter.

Berry juices, pomegranate juice, and lemon juices are converted into sirups by the addition of sugar; grape guice, apple juice, orange juice, and pineapple juice are concentrated by freezing and centrifuging or by vacuum-pan concentration, as described in Chapter 13.

The sirups are preserved by pasteurization, by sodium benzoate, or by cold storage.

Berry sirups and pomegranate sirup are made to about 35 to 45° Balling; grape juice is concentrated to about 60° Balling; and other juices, except orange, to about 55° Balling. Orange juice is slightly sweetened with cane sugar and concentrated to about 72 to 75° Balling.

Carbonating and Bottling. In using the sirup, about 1½ fl. oz. of the sirup is added to each 7-oz. soda-water bottle. Carbonated water at 30 to 40 lb. pressure is added to fill the bottles. The bottles are sealed with Crown caps at once and are then placed in a pasteurizer and heated to 150°F. for 30 min.

Standard soda-water-bottling equipment can be used for carbonating, bottling, and pasteurizing.

The cost of the fruit and sugar for the sirups used in a 7-oz. bottle of the carbonated beverage will in most cases not exceed 2 cents. The beverages can be sold retail for not to exceed 10 cents per 7-oz. bottle, with fair profit to all concerned in the manufacture and distribution of the beverage.

REFERENCES

Unfermented Fruit Beverages

The APV paraflow heat interchanger, Walker-Wallace Co., Buffalo, N.Y., 1955. A circular.

Atkinson, F. E., and Strachan, C. C.: Preservation of color in the milling of apples for natural apple juice, *Food Technol.*, **4**(4), 133–135, 1950.

——— and ———: Production of juices, *Can. Dept. Agr., Summerland, B.C., Expt. Farms Serv. Tech. Bull.* 68, 1949.

Baier, W. E., and Stevens, J. W.: Lemon and other citrus juices, chap. 13 in D. K. Tressler and M. A. Joslyn, "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

Berkness, R.: High speed processing and cooling of juice in cans, *Fruit Products J.*, **18**(12), 356–358, August, 1939.

Boyd, J. M., and Peterson, G. T.: Quality of canned orange juice, *Continental Can Co., Research Dept., Bull.* 2, 1945.

Braverman, J. S.: "Citrus Products. Chemical Composition and Chemical Technology," Interscience Publishers, Inc., New York, 1949.

California becomes important grape juice producer, *Western Canner and Packer*, August, 1951, pp. 39–41.

CARPENTER, D. C., PEDERSON, C. S., and WALSH, W. F.: Sterilization of fruit juices by filtration, *Ind. Eng. Chem.*, **24**, 1218–1223, 1932.

CELMER, R., and CRUESS, W. V.: Experiments on the canning of apple juice, *Fruit Products J.*, **16**, 356–359, August, 1937.

CHANDLER, F. B. and HIGHLANDS, M. E.: Blueberry juice, *Food Technol.*, **4**(7), 285, 286, July, 1950.

CHARLEY, V. L. S., and HARRISON, T. H.: Fruit juices and related products, *Imp. Bur. Hort. Plantation Crops, East Malling, Kent, Tech. Commun.* 11, 1939.

CHEFTEL, H., ROEBBEN, G., and MAILLET, J.: Jus des fruits et des légumes aux États-Unis, *Établissements J.-J. Carnaud et forges Basse-Indre, Lab. recherches, Bull.* 10, 1951.

CRUESS, W. V.: Apricot, peach and plum juices, *Fruit Products J.*, **16**, 231–233, April, 1937.

———: Apricot juice, *Canner*, **83**, 22–24, 1936. Also *Fruit Products J.*, **13**, 205, 1934.

——— and AREF, H.: Studies on the death temperature of Saccharomyces ellipsoideus, J. *Bacteriol.*, **27**(5), 443–452, May, 1934. Also *Fruit Products J.*, **12**, 358, 359, 377, 1933.

——— and CASH, L.: Canning of California grape juice, *Fruit Products J.*, **15**, 357–358, 364, 1936.

——— and IRISH, J. H.: Fruit beverage investigations, *Univ. Calif. Expt. Sta. Bull.* 359, 1923.

———, LEONARD, S., and PONTING, JAS. A.: Prune juice experiments, *Fruit Products J.*, **20**(7), 196–198; (8) 233, 234, 251; 1941.

——— and RIVERA, W.: Fresh juice of Italian variety prunes, *Canner*, **112**, Mar. 31, 1951, 112, p. 11.

CURL, A. L., and VELDHIUS, M. K.: Origin of the off flavor which develops in processed orange juice, *Fruit Products J.*, **26**, 329–331, 342, 1947.

Diatomaceous silica in filtration processes, Johns-Manville Corp., New York, 1930.

FMC super juicer, Riverside, Calif., Food Machinery Corporation, 1955. A circular.

———: Frozen orange juice, *Food Inds.*, **18**(5), 84–88, May, 1946.

GORE, H. C.: Studies on fruit juices, *U.S. Dept. Agr. Bull.* 241, 1915.

HARTMANN, B. G., and TOLMAN, L. M.: Concord grape juice: manufacture and chemical composition, *U.S. Dept. Agr. Bull.* 656, 1918.

HEID, J. L.: Modern techniques produce quality citrus products, *Food Inds.*, **17**, 626–629, 1945.

HENDRICKSON, R., and KESTERSON, J. W.: Citrus by-products of Florida, *Florida Agr. Expt. Sta. Bull.* 487, 1951.

HITE, B. H., GIDDINGS, N. J., and WEAKLEY, C. E., JR.: The effect of pressure on certain microorganisms, *West Va. Expt. Sta. Bull.* 146, 1914.

IRISH, J. H.: Utilization of pomegranates, *Fruit Products J.*, **6**, 11–14, 1926.

JOSLYN, M. A.: Retaining flavor and vitamins in fruit juices, *Fruit Products J.*, **16**, 234–236, April, 1937.

——— and MARSH, G. L.: Commercial production of fruit juices, *Univ. Calif. Agr. Expt. Sta. Circ.* 344, 1937.

——— and ———: Possibilities and limitations in the canning of orange juice, *Food Inds.*, **5**, 172–173, 1933. Also *Fruit Products J.*, **14**, 45–50, 1934; *Canner*, **82**(4), 26, 29–30, 85, 1936.

———, MIST, S., and LAMBERT, E.: The clarification of apple juice by fungal pectic enzymes, *Food Technol.*, **6**(4), 133–139, 1952.

KERTESZ, Z. I.: A new method of enzymic clarification of unfermented apple juice, *N.Y. State Agr. Expt. Sta. Bull.* 589, pp. 1–10, 1930.

KILBUCK, J. H.: Observations on prune juice, *Fruit Products J.*, **23**(3), 68–70, 91, November, 1948.

LAVOLLAY, J., and PATRON, A.: "Les jus des fruits," Institut des Fruits et Agrumes Coloniaux, Paris. Obtainable from Société d'Éditions Techniques Coloniales, Paris, 1948.

MARSH, G. L.: The canning of grape, berry, and apple juice, *Fruit Products J.*, **16**, 271–274, May, 1937.

MARSHALL, R. E.: Relation of clarifying treatments to sedimentation in apple juice, *Fruit Products J.*, **16**, 329–330, 1937.

MEDBERY, H. E.: The manufacture of carbonated beverages, American Bottlers of Carbonated Beverages, Washington, D.C., 1945. A bulletin.

MEHRLICH, F. P.: Pineapple juice, chap. 10 in D. K. Tressler and M. A. Joslyn, (eds.) "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

MRAK, E. M.: Prune juice, *Fruit Products J.*, **16**, 230, April, 1937.

NEUBERT, A. M., and VELDHUIS, H.: Clouding of apple juice, *Fruit Products J.*, **23**(11), 324–329, 347, July, 1944.

PEDERSON, C. S.: Grape juice, chap. 14 in D. K. Tressler and M. A. Joslyn, (eds.), "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

———: Flash pasteurization of apple juice, *Ind. Eng. Chem.*, **30**, 954–960, 1938.

——— and Tressler, D. K.: Improvements in the manufacture and preservation of grape juice, *N.Y. State Agr. Expt. Sta. Bull.* 676, pp. 1–29, 1936.

POORE, H. C.: Passion fruit products, *Fruit Products J.*, **14**, 264, 268, 285, 1935.

POWER, F. B., and CHESTNUT, V. K.: The occurrence of methyl anthranilate in grape juice, *J. Am. Chem. Soc.*, **42**(7), 1741–1742, July, 1921.

PROSSER, D. S., GRIERSON, W. F., JR., THOR, E., NEWHALL, W. F., and SAMUELS, J. K.: Bulk handling of citrus fruit, *Gainesville, Fla., Agr. Expt. Sta. Bull.* 564, June, 1955.

PRUTHI, J. S., and GIRDHARI, LAL: Technological aspects of manufacture of passion fruit juice and squash, *Chemical Age* (*India*), **6**(2), 39–48, July, 1955.

ROUSE, A. H., and ATKINS, C. D.: Heat inactivation of pectinesterase in citrus juices, *Food Technol*, **6**, 291–294, 1952.

SCOTT, W. C.: Pretreatment of grapefruit for juice canning, *Canner*, **93**(18), 11, 1941.

SMOCK, R. M., and NEUBERT, A. M.: "Apples and Apple Products," Interscience Publishers, Inc., New York, 1950.

STEVENS, J. W., PRITCHETT, D. E., and BAIER, W. E.: Control of enzymatic flocculation of cloud in citrus juices, *Food Technol.*, **4**, 469–473, 1950.

TRACY, R. L.: Sterilization of fruit juices by electricity, *Fruit Products J.*, **10**, 269–271, 1931.

TRESSLER, D. K., and JOSLYN, M. A.: "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

VON LOESECKE, H. W.: Orange juice, chap. 12 in D. K. Tressler and M. A. Joslyn (eds.), "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

WIEGAND, E. H., and YANG, H. Y.: Commercial preservation of apple juice, *Corvallis, Ore., Agr. Expt. Sta. Bull.* 487, September, 1950.

WILLIMAN, J. J., and KERTESZ, Z. I.: The enzymic clarification of grape juice, *N.Y. State Agr. Expt. Sta. Tech. Bull.* 178, pp. 1–15, 1931.

CHAPTER 13

FRUIT AND VEGETABLES SIRUPS AND CONCENTRATES

Maple, sorghum, and cane sirups have long been standard food products. Before the discovery of America the Indians used the concentrated sap of the maple as a food. The early white settlers quickly adopted the product and improved upon the crude methods of manufacture used by the aborigines.

Later, sorghum was planted in the Middle West and cane in the South to supply raw material for sirup. The manufacture of sorghum and cane sirups has become an important industry.

Fruit concentrates and sirups are becoming popular for the preparation of beverages and soda-fountain specialties and in certain cases provide an outlet for the lower grades of fruits. Frozen citrus concentrates have become very important. Starchy vegetables, particularly sweet potatoes, have been investigated successfully as sources of sirup.

Types of Sirups. A number of different types of sirups are produced commercially.

Table Sirups. Most table sirups are made by dissolving cane sugar or corn sirup, or a combination of the two, in water and flavoring the solution with imitation maple, vanilla, or other suitable flavoring. In some sections of the United States, particularly in the South and Middle West, the sap of sorghum cane and sugar cane is concentrated to a heavy sirup for table use.

Cooking Sirups. Molasses is a by-product of the sugar industry and is the mother sirup remaining after the crystallization of the sugar. It consists largely of a concentrated solution of invert sugar and dissolved uncrystallizable solids. However, concentrated pure cane juice is also often called "molasses." It is edible and is used extensively in cooking, particularly in the preparation of gingerbread, cookies, imitation brown bread, etc. Beet molasses is not edible.

"Sorghum molasses" is really a sirup rather than a true molasses because it contains the whole cane juice from which sugar has not been crystallized.

Fountain and Bottling Sirups. Under this heading are listed a great variety of sirups, most of which are wholly or in part synthetic preparations.

Examples are ginger-ale sirup and similar sirups and imitation fruit flavors like orange, lemon, lime, cherry, and berry. It is not our purpose to describe the manufacture of these synthetic preparations.

Real fruit sirups are now coming into greater favor for these uses. Most of these are fruit juices sweetened with cane sugar and preserved by pasteurizing or by sodium benzoate.

Concentrates. These consist of the whole fruit juices concentrated *in vacuo* or by other means to the consistency of heavy sirups. Usually sugar is not added.

METHODS OF CONCENTRATION AT ATMOSPHERIC PRESSURE

Many sirups are prepared by concentrating a juice, sap, or saccharified extract to a sirupy consistency. The method of concentration varies considerably, according to the character of the raw material and the size of the plant.

Open Concentrators. The simplest form of concentrator is an open kettle, which may be heated by direct flame, by a steam jacket, or by a steam coil.

Direct-fired Kettle. This may consist of a cast-iron kettle placed over a firebox in which wood or other fuel is burned. Sirup produced in such an outfit is usually severely caramelized and darkened by overheating and by iron salts formed by the action of the juice on the iron.

Sorghum Pan. A great improvement upon the direct-fired cast-iron kettle is the so-called "sorghum pan" used for maple, cane, and sorghum sirups. This is a shallow rectangular pan (not more than 4 to 6 in. deep) made of copper, tin-lined copper, galvanized iron, or very heavy tin plate, and it rests on a firebox. It is divided crosswise into sections with thin strips of metal, and the sections are connected, giving in effect a zigzag path which the juice follows during the boiling process. Galvanized iron is not desirable because the zinc coating is attacked by the juice. The fresh sap or juice enters the firing end of the pan, and the finished sirup is drawn off at the chimney end. The operation is continuous.

The pans vary in length from about 6 to 8 to about 15 ft. and can be lifted from the firebox to permit cleaning.

In using the pan the bottom is first covered with water, and the juice to be concentrated is then allowed to run into the upper end of the pan to displace the water. As it flows through the zigzag channel of the pan it is concentrated by boiling. The rate of flow is so adjusted that sirup of the required density flows continuously from the outlet. A shallow layer of juice in the pan permits more rapid concentration than does a deep layer and for this reason gives a sirup of lighter color and of less scorched flavor.

During boiling, the sirup must be skimmed frequently to remove coagulated protein, etc.

Some sirup manufacturers use two pans. In the first the juice is partially concentrated to cause clarification. The thin sirup thus obtained is then filtered, and concentration is completed in the second pan.

Steam-heated Pans. The steam-heated pan evaporator, similar in principle to the sorghum pan, is a long shallow open wooden box, lined with copper or tin, in which the juice is boiled by a closed steam coil, usually of copper. The coil extends the full length of the evaporator and is removable.

The coil is covered with juice to a depth not to exceed 1 in. above the coil. The method of operation is the same as for the sorghum pan, but there is less danger of scorching, and the rate of concentration can be more accurately controlled than in the sorghum pan. It has been used commercially for making "boiled cider," an apple sirup used in mincemeat and in cooking.

Steam-jacketed Kettles. Steam-jacketed jelly kettles can be used for the preparation of sirups, but because the boiling process is necessarily prolonged, the product is apt to be of dark color and scorched in flavor.

Kettles Heated by Coils. Tomato-purée kettles of glass-lined steel or wooden tanks fitted with copper flash coils are also used for the concentration of sirups. They are open to the objection noted above for steam-jacketed kettles.

Superheating and Film Concentrators. Tomato purée is concentrated in one evaporator at atmospheric pressure by superheating the purée and allowing it to flash boil into a vertical tubular steam-jacketed evaporator. It boils and froths upward out of the top of the column. Three such passages concentrate it to a paste. This concentrator is also used as a descending film evaporator at atmospheric pressure or as a single-pass vacuum pan.

Concentration by Solar Heat. Wet clothes dry rapidly when hung on a line in the open air on sunshiny days, and drying is hastened if the day is windy.

These principles have been taken advantage of in a process for concentrating sugary liquids. The liquid is placed in a pan or tank; cheesecloth is dipped in the juice and hung above the tank to dry. In drying, water is removed by solar evaporation and a concentrated solution remains on the cloth. The cloth is wrung out, dipped in the juice, and dried repeatedly until the liquid in the reservoir has attained the desired concentration.

This method is particularly adaptable to small-scale operations, yielding a sirup of brown or dark-amber color and pleasing flavor, but to the author's knowledge it has never been used on a large commercial scale.

Spray Process. Milk is concentrated to a powder by forcing it in the form of a fine spray into a large chamber through which a current of heated air passes. The same principle and apparatus have been applied successfully to the concentration of some fruit juices to a powder.

In one form of spray-drying apparatus the liquid is sprayed into a large

chamber into a current of heated air and the resulting powder is recovered in air-settling chambers or bag filters beyond the drying chamber.

In another machine the drying chamber consists of an inverted cone surmounted by a large cylinder, all of sheet metal, into which air heated by steam coils is forced tangentially by a powerful fan. The air is thus given a whirlwind motion within the chamber. The liquid is sprayed from a nozzle into the center of the "whirlwind," the droplets travel outward from the center toward the walls by centrifugal force, and as they travel meet air of increasing temperature and decreasing humidity. When they reach the walls, they have dried to a powder and settle into the conical bottom of the chamber as a fine dust.

The spray process can be used for drying some fruit juices, although it is usually necessary to mix with the juice milk, milk sugar, corn sirup, or dextrose to prevent formation of a sirup after drying. In experiments made with grape juice with a milk-drying machine, it was found that although the juice was dehydrated successfully, it melted at the temperatures used in drying (130 to 240°F.), because of the large proportion of fructose in the juice. On cooling, the product became solid and glasslike in appearance but was very hygroscopic and became a sirup after a few hours' exposure to air.

Lemon juice and orange juice have been dried successfully by the Merrill-Soule Company and others, after the addition of refined corn sirup.

Concentration by Freezing. It has long been a common practice in the making of maple sirup to permit the sap to freeze. Ice separates in practically pure form, leaving a sap concentrated in proportion to the amount of ice that has formed. This principle has formed the basis of several methods of concentrating fruit juices and other solutions.

Gore Process. In a process described and tested upon a commercial scale by Gore, the juice is placed in a freezing room or in ordinary ice cans surrounded by cold brine and is frozen to a mushy mixture of ice crystals and dilute sirup or is frozen to a solid cake. It is then broken up by an ice crusher and is placed in the basket of a sugar centrifuge operated at moderate speed. This basket, a perforated cylinder attached to a vertical shaft, is surrounded by a heavy metal wall. The whirling of the centrifugal forces the sirup through the openings in the basket, and the ice remains in the basket, where it may be washed free of sirup by a fine spray of water while the centrifuge is still in motion. The sirup collects in the chamber surrounding the basket and flows from the centrifugal by a suitably arranged outlet pipe.

The sirup is dilute and must be frozen and centrifuged at least once again to obtain 50° Balling. The second freezing is carried out at a lower temperature than the first, because concentration lowers the freezing point. The author has obtained satisfactory results by conducting the first freezing

at 10 to 15°F. and subsequent freezings (usually three) at 0 to 5°F. A sirup of 54° Balling was obtained. This must be held in cold storage or pasteurized to prevent spoiling.

Juice concentrated by freezing possesses a richer fresh-fruit flavor than that concentrated by other common processes, because the flavor and aroma of the fresh juice are not evaporated.

This method at one time was used commercially in the Hawaiian Islands at Pearl Harbor for the concentration of pineapple juice. Stahl has done much research and development work on concentration by freezing.

Energy Requirement. The latent heat of freezing of water is 80 cal. and of evaporation 537 cal., nearly seven times as much energy being required to evaporate as to freeze a unit quantity of water. Therefore, theoretically at least, it should be more economical to concentrate a fruit juice by freezing than by the direct application of heat. In practice, however, the freezing process has proved more costly: its less direct use of energy involves development of mechanical energy, sometimes from burning fuel, and conversion of the mechanical energy to heat energy, with loss of energy in both operations; and a large amount of handling is necessary in repeatedly freezing and centrifugalizing the juice and sirup.

Monti Process. In the Monti process the sirup and ice crystals are separated by draining, and a centrifuge is not employed. This process is in commercial use in Italy.

Linde-Krause Procedure. According to Kertesz, in this procedure, used in Germany, the juice is frozen on the outside of a refrigerated drum which revolves slowly. Inside the drum are freezing coils cooled by direct expansion of ammonia. Ice is removed from the drum by a scraper. The lower part of the drum dips into a trough of juice, which becomes concentrated by freezing of its water on the drum.

CONCENTRATION IN VACUO

Boiling in the open usually results in caramelization of the sugars of the liquid undergoing concentration and in excessive loss of flavor by evaporation and decomposition through heat. If the atmospheric pressure is to a large degree removed by placing the liquid under a vacuum, the boiling point of the liquid is reduced and much of the harmful effect of high boiling temperatures is avoided.

Relation of Boiling Point to Vacuum in Inches of Mercury. Barometric pressure is usually expressed in inches of mercury. Vacuum degree is usually expressed in a similar manner, although reduced pressure (or "vacuum") is also often expressed in inches of mercury pressure or millimeters of mercury pressure. Thus, 2 in. pressure is approximately equal to 28 in. vacuum.

A perfect vacuum at sea level would be 0 in. positive pressure, or approximately 29.9 in. vacuum.

At atmospheric pressure at sea level water boils at approximately 212°F., and in a perfect vacuum the boiling point is below the freezing point of water (32°F.); in fact, ice can be made by placing water under a very high vacuum.

TABLE 29. RELATION BETWEEN TEMPERATURE AND PRESSURE OF SATURATED STEAM UNDER VACUUM

Temperature of condenser water, °F.	Pressure, pounds absolute	Vacuum, in. of mercury
32	0.0886	29.82
35	0.0999	29.80
40	0.1217	29.75
45	0.1475	29.70
50	0.1780	29.64
55	0.2140	29.56
60	0.2562	29.48
65	0.3054	29.38
70	0.3626	29.26
75	0.4288	29.13
80	0.5050	28.97
85	0.5940	28.79
90	0.6960	28.58
95	0.8130	28.35
100	0.9460	28.07
105	1.0980	27.75
110	1.2710	27.41
115	1.4670	27.01
120	1.6890	26.56
125	1.9380	26.04

SOURCE: After E. E. Horstmann, "Steam Condensing Plants."

At 29 in. vacuum, water boils at a temperature below 80°F., a temperature that results in no caramelization of fruit sugars and in very little injury to color and flavor. Table 29 gives the relation between vacuum and the boiling point of water. Owing to the presence of dissolved solids, sirups boil *in vacuo* at temperatures somewhat above those given for water.

General Description of Calandria-type Vacuum Pans. A commercial vacuum concentrating apparatus is commonly known as a vacuum pan.

Boiling Chamber. The primary part of a vacuum pan is a vessel in which the liquid is heated. This is usually cylindrical, fitted at the bottom with a steam jacket, and contains large steam coils or a tubular calandria to heat

the liquid. A large outlet at the top connects to a vapor condenser and a vacuum pump.

The pan is often constructed of copper but may be made of glass-lined steel or of aluminum, stainless steel, or other material resistant to the action of juices.

Walls. The walls must be heavy so that they do not collapse when a vacuum is applied. The bottom must be particularly heavy because the steam pressure in the jacket and the vacuum in the pan operate in the same direction. Thus a steam pressure of 50 lb. per sq. in. and a vacuum of 29 in. would be equivalent to about 65 lb. total strain per sq. in.

Traps and Valves. The pan should be surmounted by an entrainment trap or dome to check the carrying over of liquid as a froth or spray. Sight glasses, inlet valves for fresh liquid, outlet valves for concentrated liquid, and a suitable device for the removing and testing of samples during the boiling process are usually provided.

Calandria. The most common heating device used in vacuum pans is the calandria. This consists of a large number of vertical steam-jacketed metal tubes resting near the bottom of the pan. The tubes are open at both ends and are joined by heavy metal plates, forming a honeycomb structure. The liquid fills the tubes and the space beneath the calandria and is heated by contact with the tubes.

For the concentration of delicately flavored fruit juices, high-pressure steam should not be used as a source of heat because of the danger of local overheating. The circulation of water at 50 to 80°F., or ammonia gas or other refrigerant in a closed system, or steam at less than atmospheric pressure, in the coils, jacket, or calandria, is less liable to cause injury. This plan has been followed in several commercial plants with marked success.

Heating Liquid outside the Pan. In one form of vacuum concentrator, the juice is heated outside the vacuum pan proper and sprayed into the vacuum chamber. Very rapid vaporization of part of the water from the juice cools it almost instantly. The partially concentrated juice collects in the bottom of the vacuum chamber, from which a pump forces it through the heater continuously and returns the heated juice to the top of the vacuum chamber as a spray. Thus the juice remains hot for only a few seconds on each trip through the heater and back to the pan. In the modern concentrators operating on this principle, fresh juice enters the system concontinuously and concentrate is removed continuously. It is used quite generally in the Western United States for concentrating tomato pulp and milk.

Concentrating from the Frozen State. Considerable interest has been shown recently in drying or concentrating fruit juices under very high vacuum from the frozen state, probably as a result of the wide publicity

given the drying of blood plasma to a powder by this method during the Second World War. Flosdorf states that foods were first reported dried by this method in 1935 by Mudd and himself.

The juice may be frozen before it is placed in the vacuum chamber, or it may be "self-frozen" by subjecting it to a very high vacuum in the vacuum chamber and providing a condenser operated at low temperature. Heat of evaporation is abstracted from the juice itself, cooling it to the freezing point. From this point heat is supplied at such a rate that sublimation of water occurs fairly rapidly but melting of the frozen juice does not occur. This method is known as lyophilization. In the method of the Chain Belt Company the juice is sprayed on and frozen on a continuous refrigerated stainless-steel belt traveling in a chamber under a very high vacuum.

Since the product is frozen or at very low temperature throughout the sublimation, drying, or concentrating period, the final concentrate or powder has not been damaged by heat and on reconstitution with water resembles the fresh juice closely. Serums and plasma have been concentrated to powders in quantity by this method very successfully.

The condenser must also be maintained at low temperature so that the moisture will sublime from the vacuum chamber to the condenser and not travel in the opposite direction.

One handicap of the process is the high cost of the equipment and the relatively high cost of operation, compared with that of the conventional vacuum pan. Flosdorf (1945) has published a very comprehensive review of the principles and methods of applying this method of drying or concentrating (see bibliography).

Serailian Process. In U.S. Patent 1,237,962, granted Aug. 21, 1917, M. K. Serailian describes apparatus and procedure in which juices are concentrated in a vacuum pan in such a manner that the vapors are fractionally condensed, one fraction containing most of the flavor. This flavor fraction is returned to the concentrate. The improvement in flavor is very striking. The Pfaudler ester-impregnation method is based upon similar principles. The first vapors removed during concentration are passed into a cold concentrate which entraps them.

U.S.D.A. Method for Sirups of High Flavor. In a paper by Milleville and Eskew (October, 1944) there is described an improved method of concentrating apple flavor which can be used in imparting a natural, fresh apple flavor to apple concentrate; and recent tests show that the same technique can be used with at least some other fruits. In brief, the method consists in heating the juice under pressure in a continuous stream to 320°F., allowing the hot juice to flash vaporize into another section of the apparatus, in which process about 10 per cent by volume of the juice is vaporized. The vapors are condensed at about 70°F. Practically all the apple esters are found in this 10 per cent, i.e., in the distillate.

The flavors and aroma in the distillate are very stable if kept in this form. The flavor-containing distillate may be used in many ways in addition to its use in flavoring apple concentrate, e.g., in flavoring candy, jelly, gelatin desserts, milk shakes, ice cream, etc. If the method of flavor concentration is applicable to other fruits in addition to apples, it should find very important industrial application.

For further details the reader is referred to either the paper mentioned earlier in this section or to other publications of the Eastern Regional Research Laboratory of the U.S.D.A., Philadelphia, where this procedure was developed by Milleville, Eskew, Morris, and others. In some respects the U.S.D.A. method resembles the earlier Serailian and Pfaudler processes; see preceding section.

The volatile flavoring constituents of strawberries are now recovered by surface condenser commercially to give an "essence" of great flavoring power.

Vacuum Pumps. Several methods of producing a vacuum, i.e., removing air and noncondensable vapors, are in commercial use.

Wet Vacuum Pump. A very common form of pump is the "wet" vacuum pump, which is usually a cylinder-and-piston pump of large diameter. It pumps not only the noncondensable gases and air but also the condensed water vapor and the water from the jet condenser used in condensing the water vapor from the pan. In commercial practice, the wet vacuum pump rarely gives a vacuum in excess of 26 in. of mercury, which is not sufficient for the satisfactory concentration of fruit sirups.

Dry Vacuum Pump. By means of a dry vacuum pump and a surface or barometric condenser it is possible to maintain under commercial operation a vacuum of 28 in. or more.

The dry vacuum pump is usually a rotary high-speed pump, the working parts of which turn in heavy mineral oil and which is similar to the small vacuum pumps in use in most analytical laboratories.

A condenser is interposed between the vacuum pump and vacuum pan in such manner that the pump cares only for air and other noncondensable gases that enter the pan through leaks or in solution in the fresh liquid.

Jet Pumps. The water-jet vacuum pump is familiar to all students of analytical chemistry. This pump, in a much enlarged form, is employed in some commercial installations. Water flowing rapidly past an opening entrains air and other gases from the pan and produces a vacuum, which varies with the water pressure, temperature, and volume of water used. It is not so satisfactory as the dry vacuum pump or the steam-jet pump.

A steam jet, or two or three such jets in series, using steam under high pressure (100 lb. per sq. in. or more) is employed in a widely used vacuum pump. This pump operates on the principle of the steam ejector used for

other purposes. It produces a high vacuum and is apparently satisfactory in commercial operation (Figures 68 and 69).

Jet Condenser. A jet condenser consists of a chamber with baffle plates into which is forced a stream or spray of cold water, which comes in direct contact with and condenses the vapors from the vacuum pan. This method

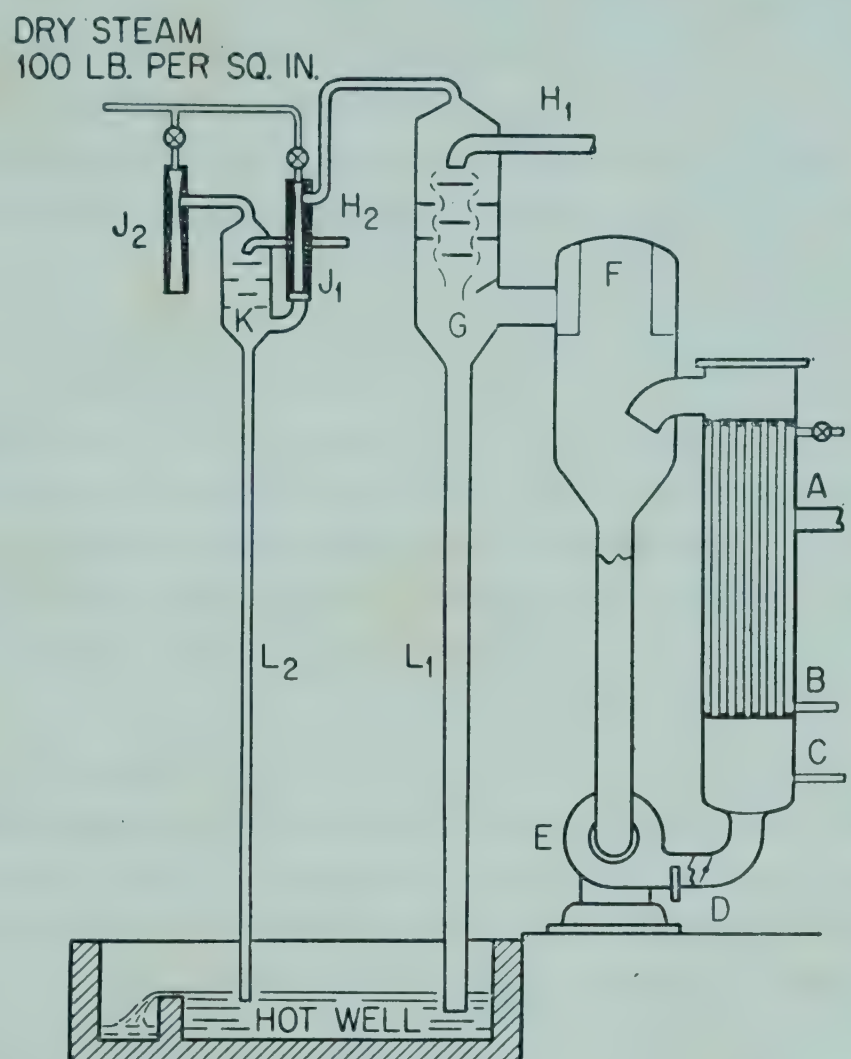


FIG. 68. Single-effect, circulating type of vacuum pan with counterflow barometric condenser and two-stage jet vacuum pump. *A*. Inlet for low-pressure steam. *B*. Outlet for condensed steam. *C*. Inlet for single-strength juice. *D*. Outlet valve and tube for pumping out concentrate. *E*. Circulating pump. *F*. Flash chamber equipped with spiral entrainment separator. *G*. Counterflow barometric condenser. H_1 and H_2. Condenser water inlets. J_1 and J_2. First and second stages of steam-jet evacuation. *K*. Small barometric intercondenser. L_1 and L_2. Barometric legs with minimum length of 35 ft. (*After Heid.*)

is efficient and economical in its use of water. The water used in the condenser and also the condensed vapors are removed by a wet vacuum pump or by means of a barometric system (Figure 68).

Surface Condenser. The surface condenser consists of a water-cooled coil or series of hollow plates or pipes into which the vapors pass and are condensed by contact with the water-cooled walls of the condenser, in much the same manner that vapors are condensed in a laboratory-size glass condenser of Liebig's pattern. Ammonia or Freon are used in such condensers (Figure 69).

Barometric Leg. The condenser may be attached to a "barometric leg" and "hot well," i.e., a vertical pipe at least 31 ft. high that dips beneath the surface of a tank or reservoir fitted with an overflow pipe (Figure 68). Water rises in the pipe in proportion to the vacuum applied to the system and flows from the hot well as rapidly as it collects in the barometric leg, or standpipe. The condenser is usually of the water-jet type but, if desired, may be a surface-cooled condenser. Such a condenser with pipe is known as a "barometric" condenser because it is in contact with the atmosphere. The barometric column of water aids in maintaining the vacuum. The barometric standpipe, or leg, must be high enough to prevent flow of water from it to the vacuum pan.

Relation of Temperature of Condenser Water to Vacuum. The lower the temperature of the condenser water or other refrigerant, the higher the vacuum it is possible to maintain in a given vacuum-concentrating system. Thus with condenser water at 32°F. it is possible to maintain a vacuum of 29.82 in., provided, of course, a suitable vacuum pump is used. If the temperature of the condenser water is 90°F., it is possible to maintain a vacuum of only 28.58 in. of mercury, referred to atmospheric pressure of 30 in. of mercury.

Table 29 gives the relation between the temperature of condenser water and the maximum vacuum. These figures also represent the relation between the boiling point of water and vacuum in inches of mercury.

Water Required for Condensing. The amount of water required for condensing a pound of steam varies greatly with the temperature of the condenser water and the vacuum degree maintained in the system. At 29-in. vacuum and condenser water at 50°F., 90 parts of cooling water are required to condense 1 part by weight of water vapor. Less water is required at lower vacuums.

Considerably less condensing water is required for a vacuum-concentrating system using a dry vacuum pump than for one using a wet vacuum pump. This is true because when the dry vacuum pump is used the difference in temperatures of the condenser water and the vapors evolved in the pan can be less. In the use of the wet pump there must be a considerable difference in temperature between the condensate and the vapors from the pan in order that the desired vacuum may be maintained. The spent water from the condenser may be cooled by passage through a cooling tower and may then be used again. Such cooling is standard commercial practice (also see section on modern vacuum concentrators).

Heat Requirements. It is a popular misconception that a great deal less heat is required to evaporate water under a vacuum than at atmospheric pressure, but the heat required in either case is that required to heat the liquid to the boiling point, plus the latent heat of vaporization of water. The latter quantity is several times greater than the former and is practi-

cally the same whether evaporation occurs at atmospheric pressure or *in vacuo.* Therefore the principal saving in heat in evaporating *in vacuo* is in that used to heat the liquid to the boiling point. Thus if the boiling point is 212°F. at atmospheric pressure and 105°F. *in vacuo* and the initial temperature of the liquid is 60°F., the liquid must be raised 152°F. if boiled in the open and only 45°F. if boiled *in vacuo.* The saving in this case would be 107°F.; or in the evaporation of 1 lb. of water, 107 B.t.u.; or in the evaporation of 1 gram of water, about 59 cal.

A British thermal unit is the amount of heat required to raise one pound avoirdupois of water one degree Fahrenheit. A small calorie (one calorie) is the amount of heat required to raise one cubic centimeter (one gram) of water one degree centigrade; a large calorie (one Calorie) is the heat necessary to raise one liter of water one degree centigrade. One B.t.u. equals 0.252 Cal. (252 cal.).

The latent heat of vaporization of water at atmospheric pressure at 212°F. is 970.4 B.t.u. and at 105°F. is 1032.9 B.t.u. Table 30, page 413, shows the relation between the latent heat of vaporization (B.t.u.'s needed to change 1 lb. of water into steam) and the temperature and vacuum at which vaporization takes place. The liquid being concentrated tends to approach in temperature its boiling point at any given vacuum. Water under very high vacuum will freeze by virtue of heat taken from it in vaporizing.

Multiple-effect Vacuum System. In sugar factories the sugary liquids are concentrated in multiple-effect vacuum pans, i.e., several pans, usually four or five, which are connected in series in such a manner that the vapors from the first pan pass through the heating system of the second and the vapors from the second pass through the heating system of the third, and similarly for the remaining members of the system.

By this method the heat applied to vaporize the liquid in the first pan is used repeatedly in succeeding pans, by the simple device of maintaining different degrees of vacuum in the different pans. This system has been used in the concentration of sorghum sirup on a large scale and in sugar factories. It is also employed in the Kelly-Howard (Carrier-Howard) triple-effect, low-temperature vacuum concentrator.

Modern Vacuum Concentrators for Fruit Juices. The principal advantages of modern vacuum concentrators for fruit juices in comparison with the older types of vacuum pans are (1) operation at lower temperatures, (2) lower temperature differences between heating medium and juice, and (3) the great rapidity of concentration, i.e., brevity of the concentration period. These concentrators are of two general types: (1) the multistage, single effect, and (2) the multiple-effect concentrators. The multistage type differs from the multiple effect in that the separate stages are all at the same vacuum and temperature, whereas in the multiple-effect each unit or effect

is at a different temperature and vacuum than the other effects. As mentioned previously, the vapor from one effect is used to heat the tubes or pan in the next effect. At present three stages or three effects are generally used in the two types of concentrators.

Water and water vapor (steam) or the gaseous and liquid phases of a refrigerant can be used as the heat source and for condensing the vapor

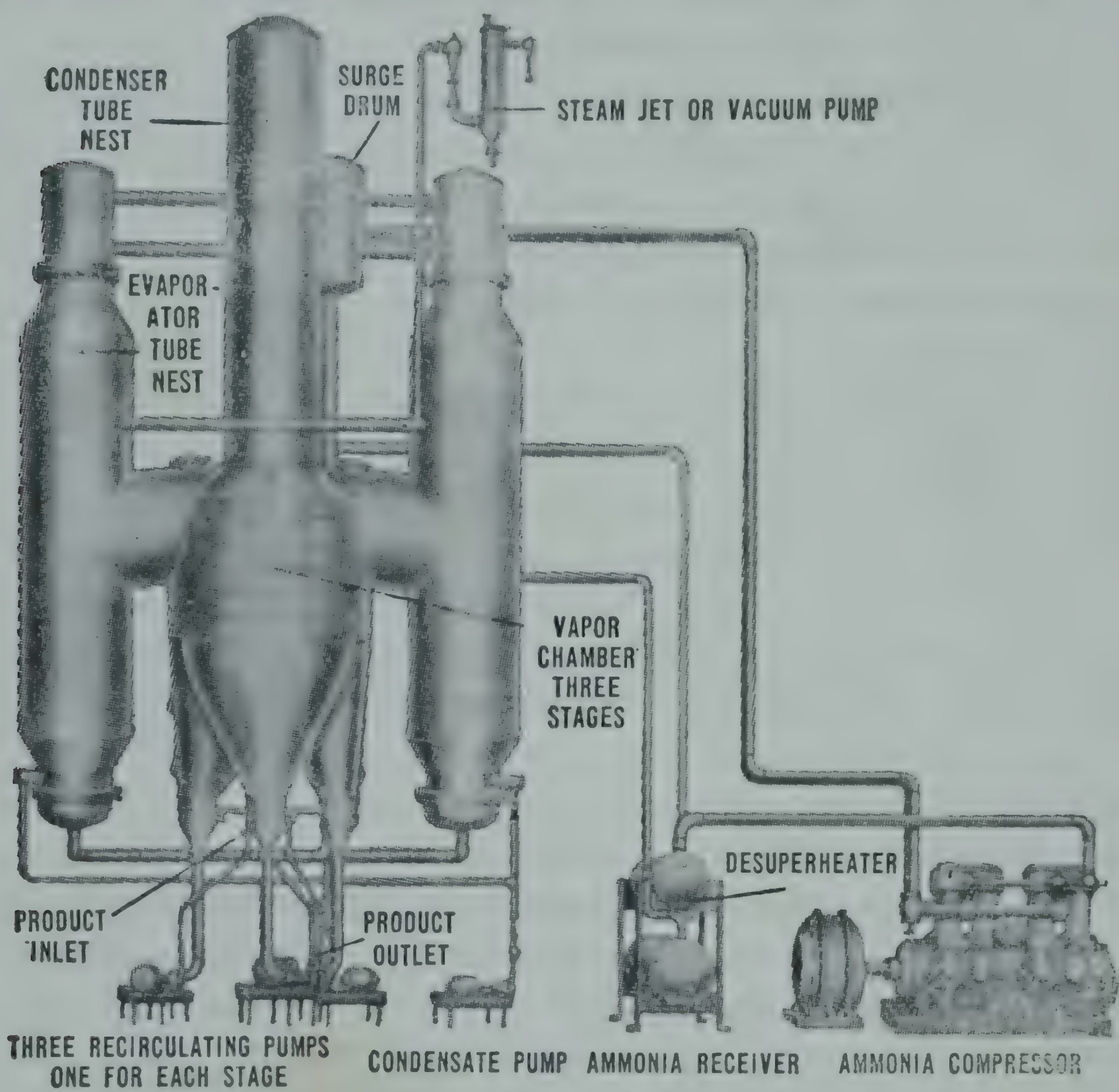


FIG. 69. Low-temperature concentrator. (*Mojonnier Bros. Co., Chicago.*)

from the juice; or a combination of refrigerant and water can be used.

The Mojonnier vacuum concentrator that the author has seen in operation in California citrus-concentrate plants is of the continuous multistage (three-stage), single-effect falling-film design. Heat required for evaporation of water from the juice is furnished by the condensation of warm ammonia gas from a refrigeration compressor. Liquid ammonia is used to cool and condense the water vapor in the distillate condenser. Freon can be used in place of ammonia.

Heid and Beisel (1948) describe the Mojonnier concentrator in use in Florida at that time as follows:

The evaporator consists of three vertical cylinders, each containing 25 three inch tubes. Pumps raise the juice to the top of these tubes, which are jacketed with

the compressed ammonia at 105°F. The bottom of the tubes is connected with a horizontal vapor separator through which the vapor moves to the condenser. The condenser is a vertical tubular heat exchanger with ammonia expanding through the tubes. A two stage ejector (steam ejector) is connected to the top of the condenser to remove uncondensibles.

The uncondensibles consist of air and other gases released by the juice under vacuum and air in very small amounts that gains entrance to the system through slight leaks in connections, etc.

Heid and Beisel state that orange juice entering the first stage at 13° Brix overflows to the second stage in about 1.3 min. at about 20° Brix and in another 1.3 min. overflows into the third stage at about 40° Brix. In a like period it reaches about 58 to 60° Brix and is pumped from this stage continuously. During concentration the juice enters the first stage at room temperature, about 70°F., and the concentrate is removed at about 50°F. The temperature range varies somewhat with the rate of feeding and the vacuum. Because of this low temperature range there is no danger of scorching of the product or burning on of juice on the walls of the tubes of the heat interchangers.

Cross and Gemmill (1948) state that in the three heat interchangers the juice boils inside the tubes and NH_3 gas or vapor condenses as liquid ammonia on the outside of the tubes. In the water-vapor condenser the vapor is condensed to liquid water on the outside of the condenser tubes by the boiling liquid ammonia in the tubes. The liquid ammonia is vaporized at 41°F., and the water vapor is condensed at 58°F. The NH_3 vapor then travels to a four-cylinder Frick compressor, where it is compressed and rises in temperature to about 103°F. It then is discharged to the three evaporating chambers where it gives up its latent heat to evaporate water from the juice.

In the evaporating chambers the boiling juice and the water vapor travel down the tubes together to a separation chamber in which, by means of baffles, decreased velocity of the vapor, and change in direction of flow, the small droplets of juice in the vapor phase are separated and returned to the juice in the bottom of the separator. A pump moves the partially concentrated juice to the next stage or the concentrate to the blending tank. All metal parts of the equipment that come in contact with the product are of stainless steel.

Another type of juice concentrator is the Kelly-Howard (also known as the Carrier-Howard) concentrator, designed by E. J. Kelly of the Howard Corporation. It is a triple-effect, falling-film type of vacuum concentrator. Such an apparatus in use in a large citrus concentrates plant in Fullerton, California, has been described in *Citrus Leaves*, 1949, by an anonymous author about as follows.

It utilizes water at 90°F. in the first effect as the heating medium, water vapor from the first effect to heat the tubes and juice in the second effect, and water vapor from this effect to heat the juice in the third effect. The water drops to 80°F. in the first effect and is then returned to the jacket of the compressor where it absorbs the heat generated in compressing the vapor of the refrigerant, Freon. The liquefied Freon is then used to chill water for the barometric condenser to about 37°F.

The sequence of events as they affect the juice, water, refrigerant, and concentrate are about as follows, according to this paper: The freshly reamed juice enters the first effect at about 75°F., or room temperature. It flows down the inside walls of the tubes, which are about 3 in. in diameter, i.e., of sufficient diameter to permit free boiling of the juice from a film of juice on the walls of the tubes and free passage of the vapors formed in boiling of the juice. This effect is at 29.125 in. vacuum, and the tubes are surrounded (jacketed) by water at 90°F. The water gives up heat to the juice, causing it to boil, and leaves this effect at 80°F. to be returned to the jacket of the refrigerant compressor. The vapors from the boiling juice flow downward with the juice into the separation chamber where any small entrained droplets of juice are removed and combined with the partially concentrated juice on its way to the second effect.

The water vapor from the first effect is then used to heat the tubes and juice in the second effect. Similarly, the water vapor from this effect travels to the jackets of the tubes in the third effect and brings about the final concentration of the juice to a concentrate of 58 to 60° Brix. The water vapor from the third effect travels to the dome of the barometric condenser where it meets chilled water at 37°F. and is condensed to liquid water at 45°F. The combined water flows by gravity down the inside of the barometric leg to the cold well, from which some overflows to the waste line and some is returned to the system.

In the first effect, according to the article mentioned above, the vacuum is 29.125 in.; the water used for heating the juice in its tubes enters at about 90°F. and leaves at about 80°F. The vapor from the juice is at about 75°F. The juice enters this effect at about 13° Brix and leaves it at about 17.6° Brix and about 75°F. The second effect is at 29.44 in. vacuum; the temperature of vaporization is about 62.5°F., and the juice leaving this effect is about 27.2° Brix on the average. In the third effect the conditions are 29.64 in. vacuum, temperature of vaporization and of concentrate about 50°F., and the final concentration of the juice about 60° Brix, although 58° Brix is also a common final concentration. The concentrate, as is also the case with the triple-stage concentrator previously described, is pumped to a blending tank where it is intimately mixed with enough fresh, deaerated juice to reduce it to 42 to 43° Brix.

According to a paper (1951) under anonymous authorship (*Western*

Canner and Packer, July, 1951) the juice may first enter the third effect, instead of the first, at about 13° Brix and 75°F. It is subjected to a vacuum of 29.152 in., concentrated to about 17° Brix, and drops to about 50°F.; in the next effect it is at a slightly lower temperature and 29.44 in. vacuum and is concentrated to about 32° Brix; and in the next effect (effect 1) it is at 29.64 in. vacuum, 62.5°F., and reaches 58° Brix.

Heid and Kelly (1953) outline several other manners of operating low-temperature vacuum concentrators; lack of space does not permit presentation here.

Other Factors in Low-temperature Concentration. Freon, the refrigerant used in the Kelly-Howard concentrator triple-effect concentrator, is nontoxic, noninflammable, and nonexplosive. On this account it is less hazardous to the workmen than is NH_3. The Freon unit is separated from the concentrating unit, and hence there is no opportunity for contamination of the juice or concentrate by the refrigerant.

The vacuum in the low-temperature, multiple-effect concentrator is maintained by two devices, or methods. First is the barometric condenser in which the water vapor from the evaporating columns is condensed to liquid by a spray of cold water; the great decrease in volume creates and maintains a vacuum. The second device is the steam ejector in which steam at high pressure and great velocity flowing past an orifice pulls air and other uncondensable gases out of the system. In commercial installations two or more such ejectors may be used in order to thoroughly remove gases and thus maintain a high vacuum. As previously noted, much of the air to be removed comes from the juice in the first effect, or the first stage.

Since the juice and the concentrate in the low-temperature evaporator (concentrator) is at room temperature or lower, microorganisms can exist and multiply. All parts in contact with the juice or concentrate should be bathed by the rapidly flowing product, and dead ends and pockets must be avoided. The evaporating tubes, condensers, pumps, pipelines, and other parts that come in contact with the product should be thoroughly cleaned at least once a day and sterilized with steam or chlorinated water. It is customary in citrus-concentrate plants to make frequent bacteriological counts by means of sampling at various critical points and making dilutions and agar plates. Special media are used for making counts of *Escherichia coli* (*Bacillus coli*) bacteria, as their presence would indicate undesirable contamination. The complete absence of this organism is an important objective. Usually the count for all organisms is very low and the usual microorganisms encountered are yeasts and molds, all of which are harmless to health. Maximum tolerances have been established.

As the concentration of the juice increases, its viscosity also increases, while its specific heat and thermal conductivity decrease. Consequently,

the heating surface per unit volume of product must be greater in the final unit of the concentrator than in the first effect, or first stage, if comparable rates of evaporation are to be attained.

Under a high vacuum, as Burton (1947) has pointed out, water vapor increases tremendously in volume compared with that at atmospheric pressure. For example, at 60°F. and high vacuum, 1 lb. of water vapor occupies about 1,208 cu. ft. This volume of vapor would be a very great load on a vacuum pump. On the other hand, if the water vapor is condensed to liquid H_2O in a surface condenser cooled by NH_3, only 2 lb. of NH_3 would be required, according to Burton.

ORANGE CONCENTRATE

Although orange concentrates were produced commercially for many years previous to 1945–1946, they were decidedly inferior to present-day frozen concentrates in that they lacked the flavor and aroma of the fresh juice and often were rather stale in flavor because of deterioration after bottling or canning. Modern concentrates are of excellent flavor and beverage quality. They date from about 1945.

According to Heid and Kelly (1953), the improvement in citrus-concentrate production that has made the tremendous increase in production of recent years possible was made by MacDowell, Moore, Atkins, and others of the Florida Citrus Commission in cooperation with the U.S.D.A. Citrus Products Laboratory of Florida in 1945 or earlier. The research was reported by Moore, Atkins, Wiederhold, MacDowell, and Heid in 1945. They had found, as had others, that concentration of the juice under even a very high vacuum and at low temperature gave a concentrate that was flat in flavor, but that if they added to this concentrate a certain amount of fresh juice they obtained a concentrate that on dilution to fresh-juice strength had a fresh flavor and aroma. In brief, they concentrated the bulk of the juice to about 60° Brix and then cut it to 42 to 43° Brix by the addition of deaerated fresh juice. On dilution of one volume of this concentrate with three volumes of water a juice that was very much like the fresh was obtained. MacDowell, Moore, and Atkinson were granted a public-service patent on the process. It became the basis for the production of frozen orange concentrate on a very large scale. The inventors suggested that the 3-plus-1 concentrate be preserved by freezing rather than by pasteurization.

Heid then left the U.S.D.A. and joined the Florida Citrus Canners' Cooperative at Lake Wales, Florida, in order to aid in the industrial development of the process and product. J. A. Cross, of the Mojonnier Bros. Co. of Chicago, designed a unique, low-temperature vacuum concentrator; and a pilot-scale plant was built by the Mojonnier Co. and

installed at the cannery in Lake Wales, Florida. It proved very satisfactory, and as soon as possible a concentrator of commercial size was built and installed.

The concentrator is a three-stage, descending-film, low-temperature, high-vacuum type, using NH_3 as a refrigerant at one point in the cycle and as a source of heat at another point. This equipment has been described earlier in this chapter. The 42° Brix concentrate was packed in 6-oz. cans and frozen for retail distribution. Consumer response was beyond all expectations. Within a short time other processors in Florida and in California installed low-temperature concentrators with very rapid increase in production.

The method used in the plant at Lake Wales was about as follows, according to Heid and Beisel: Selected fruit was carefully sorted to remove oranges unfit for juice; the fruit was washed, sorted again, washed a second time; the juice was extracted and screened to remove about 10 per cent together with the juice sacs; the screened juice was concentrated in the Mojonnier concentrator at low temperature to about 60° Brix and transferred to a refrigerated closed tank in which it was blended with deaerated fresh juice to reduce the concentrate to 42° Brix. It was cooled to 25°F., partially frozen to a slush at 16°F., canned in 6-oz. cans, sealed, and frozen solid in the cans on coils at −10°F. It was stored at −10°F. until shipped. This is essentially the process now in general use.

In a large California plant the procedure in 1955 was approximately as follows:

Well-matured oranges of the Valencia variety were delivered in bulk by truck and placed in large baffle-type storage bins. Samples of fruit from each load were taken for analysis of the juice for ascorbic acid content, Brix degree, and total acidity. The oranges were conveyed from the bins by belt past a sorting crew. The fruit was then soaked and washed in water containing a generous amount of detergent and washed very thoroughly a second time by rapidly revolving brushes and heavy sprays of water. The oranges were next rinsed in water containing sufficient free chlorine to destroy most of the microorganisms still remaining on the skins of the fruit. A second sorting followed. The oranges were then graded by machine into four sizes, since the juice extractors work best with fruit of uniform size. The juice was extracted by Brown extractors in which each orange is cut in half and the juice automatically reamed out; screened to remove seeds and coarse membrane and other coarse particles; and then passed through a high-speed continuous centrifugal. It was next flash pasteurized at 165°F. to inactivate the enzyme pectinesterase and immediately cooled. It was held in refrigerated tanks until it went to the concentrator.

In a Kelly-Howard triple-effect, low-temperature concentrator the juice

was concentrated to 57 to 58° Brix and delivered to a closed, refrigerated blending tank. Deaerated single-strength fresh juice was then added to give a blend of 42 to 43° Brix. This was deaerated, frozen to a slush at 16°F. in a Votator Continuous Slush-Freezing Apparatus, canned, sealed, and passed through an FMC immersion freezer. Freezing was then completed in an air-blast freezing tunnel, and the cans stored at −10°F.

In another plant the operations are similar to the foregoing except that freezing of the concentrate in the cans is completed in an immersion freezer. In both plants only 5 to 7 min. time elapses between reaming of the juice and canning of the concentrate, and less than 30 min. elapses from reaming to final storage at −10°F.

Considerable difficulty has been encountered with clotting and separation of juice and pulp in 42 to 43° Brix frozen-pack concentrates because of the action of the enzyme pectinesterase when the enzyme has not been inactivated by flash pasteurization of the juice. In such cases the pulp settles on dilution, leaving a more or less clear "serum." Although early experiments by Irish and the author showed that the enzyme is quite heat-resistant, requiring flash heating to about 190°F. for complete inactivation, heating to 165°F. evidently reduces its activity sufficiently to give a reasonably stable concentrate.

Moore (1949) has published tables giving the gallons of juice of various Brix degrees required to reduce concentrate of given Brix degree to 3-plus-1 strength, 43° Brix. However, each plant usually prepares its own dilution schedule applicable to its conditions. Also, automatic control of blending is now in use in which the human element is completely eliminated.

The 3-plus-1 concentrate is sold from frozen-food cabinets in grocery stores throughout the United States and Canada. On diluting with three parts of water it is used as a breakfast beverage and in the many other ways in which fresh orange juice is consumed.

During the first year of production, 1945, it is estimated that about 250,000 gal. of the frozen-pack concentrate was produced; in 1952 it reached about 50 million gal., and production in 1956 is estimated at about 70 million gal. per year, according to recent news notes in the trade journals. This would be equivalent to about 280 million gal. of fresh juice, or about 1,470 million cans of 6-oz. size of the concentrate.

As previously mentioned, care must be taken to prevent increase in the numbers of microorganisms during concentration and other operations in the production of citrus concentrates. All equipment with which the juice and the nonfrozen concentrate comes in contact should be kept scrupulously clean and should be sterilized with steam or chlorinated water regularly. Murdock, Brokaw, and Allen have found that the cooling section

of plate-type heat interchangers may become a location for build-up of microorganisms in the juice.

During the early period of frozen-orange-concentrate production plain tin cans were used, but it was found, as reported by Riester and Ayres (1955), that because temperatures during transportation and during handling and storage in grocery stores are often much above the freezing point of the concentrate, reaction between the concentrate and tin plate of plain tin cans may result in formation of a black compound of iron in the head space. Use of enamel-lined cans has entirely prevented this discoloration in recent years. All orange concentrate is now packed in the enamel-lined containers. Up to the present time other types of containers, such as plastic bags, glass jars, etc., have not proved practicable because of cost, fragility, difficulty of hermetic sealing or for other reasons. Outside corrosion of the end of the can has occurred occasionally, especially when stored in home refrigerators, but the extent of such corrosion has been very minor.

Stahl (1944) reported on an improved method of concentrating citrus juices by the freezing process, and his method has been used for commercial production of concentrates. A product of high degree of fresh flavor is obtained. Because of some loss of solids in the ice phase formed in the process and greater cost of production in comparison with low-temperature vacuum concentration, the freezing process has not come into general use. However, Wright (1955) has called attention to a process now in use in the plant of the Golden Gift Co., Inc., Florida, in which part of the juice is concentrated by freezing and centrifuging to obtain a concentrate of rich flavor, which is then combined with a concentrate made by concentrating *in vacuo* the 85 per cent of the juice remaining after freezing concentration. This concentrate is of approximately 57° Brix. The blend consists of 15 gal. of concentrate of 30° Brix, made by the freezing procedure, and 10.2 gal. of vacuum-concentrated juice of 56.9° Brix. The resulting 25.2 gal. of concentrate of 42° Brix represents 100 gal. of fresh juice.

As stated earlier in this chapter, the clotting, jelling, and separation of suspended solids and liquid in citrus concentrates have been a serious problem. Joslyn and Sedky (1940) reported that a pectic enzyme is responsible and indicated a method of control by heat inactivation of the enzyme. Guyer, Miller, Bissett, and Veldhuis have reviewed this problem and have reported upon extensive experiments on its control by heat inactivation. They state that heating to 150°F., except for several of the shorter holding times, reduced the pectinesterase activity to 25 per cent or less of its original value. There was a marked increase in cloud stability (decreased separation) in the range of 170 to 180°F. without corresponding

change in enzyme activity, indicating that some other factor than enzyme activity is also involved.

Orange sirup made by adding sugar to fresh juice is in demand for the preparation of carbonated beverages.

In some cases the juice is extracted by crushing and pressing the entire fruit. The juice should be flash pasteurized, i.e., heated to 190 to 195°F., for a few seconds before conversion into sirup in order to destroy the enzymes responsible for clotting and changes in flavor during storage of the sirup. The usual method of preparing the sirup is to add 12 lb. of sugar per gallon. The sirup should be placed under 28 to 29 in. vacuum at room temperature for 25 to 30 min. to remove dissolved air and should then be sealed airtight in completely filled bottles, lacquered cans, or jugs. The presence of air in sirup or container causes the flavor to oxidize and become "terpeney."

Havighorst (1945) described the production of orange concentrate preserved by heat in a California plant as follows: The juice is extracted by Citromat or crusher rolls, screened, centrifuged to remove oil, deaerated, flash-heated to 190°F., concentrated *in vacuo* to 65° Brix at not above 110°F., heated to 160°F., canned, and cooled.

Sirup is also prepared commercially as follows: The juice is strained through a coarse screen, and sugar to increase the Balling to 65 to 70° is added, together with benzoate of soda, $\frac{1}{10}$ per cent. Lemon juice or citric acid may also be added.

Another popular product is prepared by partially concentrating the juice *in vacuo* and adding cane sugar. The sirup is pasteurized in cans or bottles and used in preparing noncarbonated drinks by diluting with water. These drinks are sold widely through dairy-products distributors. The sirup usually contains added citric acid.

LEMONADE SIRUP OR CONCENTRATE

Lemons are grown in the United States almost exclusively in California and Arizona. The juice contains from about 4.5 to 7.5 grams of citric acid per 100 cc., an average of about 6 grams per 100 cc.

Lemonade sirup made by addition of sugar to give a product of about 60° Brix has been on the market for many years, although it has never become very popular, because when held at ordinary temperature in bottles or cans it deteriorates in flavor, odor, and color rather rapidly. A similar product made from lime juice and sugar for dilution for use as limeade, or, as it is called in Britain, "squash," is quite popular in the British Isles.

With the advent of frozen orange concentrate interest became general

in the production of frozen concentrated lemon juice or of a sirup made of juice and added sugar. The latter became much the more important product and is now produced in several large plants in southern California. The industry decided early in this development to name the product "concentrate for lemonade" rather than "sirup." Its production is discussed in Chapter 25 in addition to the summary given later in this chapter.

In 1945, at the University of California, Cruess, Glazewski, and Seagrave-Smith conducted experiments on frozen lemon concentrate and on the sweetened product to be used for lemonade. The experiments were reported in 1946. It was found that the unpasteurized, unsweetened juice almost invariably curdled during freezing storage and thawing, but that if sweetened to 50° Brix with sugar, curdling did not occur, even after 1½ years' storage at 0°F. Also, this degree of sweetness gave on dilution with water a lemonade of optimum sweetness and acidity. However, Cole (1955) states that consumer-taste trials conducted by the producers and the U.S.D.A. indicate that the average consumer is not very discriminating in so far as lemonade is concerned and that a rather wide range in Brix degree of the concentrate in commercial practice could be used. However, 50° Brix appears to be the present standard in the industry.

Also, Cole states, the Exchange Lemon Products Company of Corona California in 1938 began packing a pasteurized lemonade sirup, or concentrate, which was used chiefly by the soda-fountain trade. It was of 59° Brix and intended for dilution with five volumes of water to give a lemonade of about 12° Brix and about 0.7 per cent total acidity as citric. It was preserved by packing hot in enamel-lined cans. If held at 40°F. or lower, it retained its fresh flavor quite well, but soon deteriorated if held at room temperature.

Cole states that the first frozen-pack lemonade concentrate was packed commercially by Damerel-Allison Company (now owned by Exchange) in California in 1949 under the Pictsweet brand name. It is now an important pack, the output for the entire state in 1954 being about 10 million cases.

The sequence of operations in several California plants in 1955 was about as follows: Lemons sorted out at the fresh-lemon-packing plants because of minor skin defects, color, shape, size, etc., but of sound quality, are delivered to the plant in bulk by truck or rail and stored in slatted bins. The lemons are again sorted to remove unfit specimens, detergent-washed, sorted a second time, brush-washed and rinsed, rinsed in dilute chlorine solution to destroy any microorganisms still on the skins, and halved and reamed by machine; the juice is screened to remove seeds and very coarse particles, sweetened to 50° Brix with cane or beet sugar, some concentrated lemon juice added if needed to balance the acidity and sugar content, partially deaerated, chilled in a Votator or other refrigerating equipment, canned in 6-, 12-, or 46-oz. enamel-lined cans, frozen in

an immersion or air-blast freezer, or both, and stored at −10°F. The foregoing outline is more or less generalized and probably does not exactly correspond to the operations in any one plant.

A typical formula for preparation of the sirup or lemonade concentrate has been given by Cole as follows:

Single strength lemon juice of 6% acid content	570 gal.
Pulp slurry (juice with juice sacs from separator)	55 gal.
Concentrated lemon juice of 32.5 grams citric acid content per 100 cc.	11 gal.
Sugar (cane or beet)	4,851 lb.

Yield, about 1,000 gal. of lemonade concentrate.

One 6-oz. can of lemon concentrate is diluted to give a quart of lemonade. California standards require that the concentrate on dilution with water as directed on the label shall give a lemonade of not less than 10.5° Brix and 0.7 gram of anhydrous citric acid per 100 cc. The Federal specifications require this same minimum for Fancy and Choice concentrate, but the interim standards permit an acidity as low as 0.6 gram per 100 cc. for B grade. They call for not more than 0.02 per cent recoverable oil from the Grade A product and not more than 0.03 per cent from the B grade.

Cole reports that the pulp content of commercially produced lemonade concentrates has been found to range from about 1.5 to 4 per cent by volume.

If the package in which the concentrate is stored is leaky, a fondantlike solid forms in the frozen product. It is a hydrated sugar compound. It does not form in tightly sealed containers. Concentrate packed in plastic bags has shown this phenomenon occasionally because of faulty sealing. It has seldom been encountered in sealed cans.

Some concentrated lemon juice is packed for use in the acidification of canned figs and for other industrial food uses. It is recommended that it be stored under refrigeration, but not necessarily frozen, until used. It darkens rather rapidly at room temperature. A 5:1 concentration has been used. A considerable quantity of the concentrate produced in low-temperature concentrators is frozen in large containers for shipment to commercial plants, which may repack it with sugar as lemonade concentrate or use it in other ways in which a product of fresh flavor is desired.

The equipment used for extracting the juice from the fresh fruit includes, according to Cole, the Brown, FMC, rotary, Citromat, and the Bireley extractors. If considerable oil is extracted with the juice, it will be necessary to remove the excess by centrifuging or by deoiling by special equipment designed for that purpose and used quite generally in Florida for juice extracted by rollers or other form of pressure extractor. It operates by flash boiling under vacuum.

OTHER FRUIT SIRUPS AND CONCENTRATES

The manufacture of sirups affords a means of utilizing a considerable portion of cull and second-grade fruit of sound condition.

TABLE 30. RELATION BETWEEN TEMPERATURE OF VAPORIZATION, LATENT HEAT OF VAPORIZATION OF WATER, AND BOILING POINT

Temperature, °F.	Vacuum, in. mercury	Latent heat, B.t.u.
32	29.8191	1073.40
40	29.7516	1068.90
50	29.6365	1063.30
55	29.5631	1060.50
60	29.4770	1057.80
65	29.3760	1055.00
70	29.2590	1052.20
75	29.1250	1049.40
80	28.9680	1046.80
85	28.7880	1044.00
90	28.5800	1041.20
95	28.3410	1038.40
100	28.0700	1035.60
105	27.7590	1032.90
110	27.4040	1030.10
115	27.0050	1027.30
120	26.5530	1024.40
125	26.0400	1021.60
130	25.4800	1018.81
135	24.8300	1015.90
140	24.1100	1013.10
150	22.4200	1007.40
160	20.3200	1001.60
170	17.7700	995.80
180	14.6700	989.90
190	10.9300	983.90
200	6.4700	977.90
210	1.1600	971.60
212	0.0000	970.40

SOURCE: After The Lillie Evaporator Co. Tables, 1918.

Grapefruit Concentrate. In Florida considerable concentrated frozen grapefruit juice is produced by the methods and equipment described

earlier in this chapter for orange concentrate. Like orange concentrate it is to be diluted with three volumes of water before serving. For household use it is packed in 6-oz. size cans and preserved by freezing as described for orange concentrate.

Limeade Sirup. Lime juice is sweetened to about 50° Brix in Florida and packed and frozen in much the same manner as described in this chapter for lemonade concentrate. It is diluted to limeade strength with water before serving or may be used in mixed drinks. For the latter use it is found to some extent in bars.

Grape Concentrate. In wineries in California important amounts of grape juice, principally white, are concentrated in standard vacuum pans, usually not of the modern, low-temperature, high-vacuum type. The resulting concentrate of 65 to 72° Brix is used for the sweetening of fortified wines such as Port, Muscatel, and others. Some is made from red wine grapes to give a highly colored concentrate useful in improving the color of Port wine. At one time, during the Prohibition period, it was available for use in making homemade wine, but it is no longer on the retail market. It is usually held in cold storage until needed in order to prevent deterioration in flavor and color.

If made from filtered red grape juice, the concentrate is a very satisfactory table sirup, although it has never been placed on the market for that purpose.

If concentrated beyond about 68° Brix, crystals of dextrose hydrate separate from the concentrate, often in such a large amount that the product becomes semisolid. Another problem is the separation of cream-of-tartar crystals on standing of the concentrate. Grape juice is supersaturated with this compound, and on concentration it must crystallize. It settles slowly or not at all in a heavy concentrate; consequently, its removal from the concentrate is difficult. It is of no consequence, however, if the concentrate is used to sweeten fortified wines, as it settles out quickly in the wine.

Since the great increase in popularity of frozen citrus concentrates, the production of Concord grape concentrate in frozen form has been undertaken in the Eastern United States and in Washington state. It is packed in small cans for the retail trade and is diluted with water, usually 3 plus 1 for serving. A satisfactory method of preparing the concentrate has been developed by the Eastern Regional Laboratory of the U.S.D.A. As described by an anonymous author in *Food*, March, 1953, the method is about as follows:

First a red grape juice is prepared from ripe Concord-variety grapes by the method described in Chapter 12. It is stored under refrigeration a sufficient time for deposition of most of its excess cream of tartar. It is then drawn off the sediment, heated somewhat above its boiling point in a

special flash type of heat interchanger, and vaporized into an essence-recovery unit of the type designed by Milleville et al. of the U.S.D.A. About 30 per cent of its volume is vaporized, and the remaining juice instantly cooled to arrest heat damage. The vapor is fractionally condensed in such a manner that the flavor constituents of the juice are held in a portion of the distillate equal in volume to about $1/150$ of the original volume of the juice; i.e., this so-called "essence" represents a 150-fold concentration of the volatile flavoring constituents of the juice.

The cooled juice that has been "stripped" of its essence is treated with a pectic enzyme overnight, filtered, and concentrated in a multistage or multieffect low-temperature concentrator to 74.9° Brix. Since the juice has been depectinized, the concentrate does not jell; otherwise it would do so. This concentrate is then blended with the essence in the ratio of 63.51 gal. of concentrate to 2.67 gal. of essence, which gives a blend of 72.8° Brix. A sugar sirup of 72.8° Brix is then added in the ratio of 33.12 gal. of sugar sirup to 66.24 gal. of grape concentrate. The blend is cooled to 40°F. after very thorough mixing and packed in small cans. These are frozen or stored at 32 to 35°F. The product keeps well in color and flavor in this range of temperature. The concentrate is intended for dilution with six volumes of water before serving. While some cream of tartar separates in the concentrate, the author of the aforementioned article states that it is not objectionable in amount.

Evidently this product is much more concentrated than the grape concentrates now on the market. Two brands on sale in stores in Berkeley in March, 1956, were 3-plus-1 products; i.e., three volumes of water is added to one volume of concentrate. The two samples were of 52 and 51° Brix, respectively, and gave on dilution with three volumes of water a juice of about 15° Brix. Probably the U.S.D.A. method described above could be used to produce a concentrate of this type (51 to 52° Brix).

Raisin Sirup. A light-colored or colorless raisin sirup suitable for use on the table and other purposes was prepared experimentally in the Food Technology Department of the University of California by Musco and others in 1954. They used ion-exchange resins to remove compounds responsible for the darkening of such sirups or concentrates. The preferred procedure was as follows:

Raisins of the Thompson seedless variety were extracted with water at 140 to 150°F. to give an extract of 20 to 25° Brix. The extracted raisins were crushed and pressed to recover remaining soluble solids.

The extract of 20 to 25° Brix was filtered and decolorized with activated carbon in order to lighten the load on the exchange resins. The decolorized extract was then passed slowly through a column of cation-exchange resin, which removed metallic ions, in this instance chiefly potassium. The treated extract was of high acidity, the acids being tartaric and malic. It was then

treated in an anion-exchange column which removed the acids, including any inorganic acids present. The extract at this point was slightly alkaline, and on that account a small amount of citric acid was added to render it faintly acidic in reaction.

The extract was next concentrated in a glass vacuum concentrating apparatus at 100 to 110°F. to 68° Brix. The concentrate was then packed in glass jars hot after flash pasteurization, and the jars rapidly cooled. The concentrate, or sirup, is essentially pure invert sirup and can be used for any purpose for which invert sirup is employed. Several experimental lots were concentrated to 80° Brix. For table use the sirup of 68° Brix was flavored with imitation maple extract. If made from cull raisins of low price, the product could probably compete in price with invert sirup; but it is doubtful whether raisins of Choice or Fancy quality could be used because their cost would be too high.

Grape Sirup for Table Use. Excellent table sirup can be prepared from clear grape juice by concentrating the juice *in vacuo* under 28- to 29-in. vacuum. If made from red grapes, it will be of deep purplish red color and of a rich, berrylike flavor, which is very desirable for table use.

It is possible to neutralize all or most of the acid of grape juice by the addition of calcium carbonate or calcium hydroxide. Insoluble calcium tartrate is formed and can be separated from the juice by settling, racking, and filtering. The calcium tartrate forms most readily at or near the boiling temperature and is most insoluble at low temperatures. Therefore the juice should be heated to facilitate the reaction and should be allowed to cool before filtration. Not all the acid should be neutralized. The juice should retain about 0.1 per cent acidity (as tartaric) after neutralization. Complete neutralization results in darkening of the sirup and renders it more liable to injury in flavor during concentration.

The partially neutralized white juice can be decolorized by the use of vegetable decolorizing carbon. A light-colored sirup of neutral flavor can then be produced by vacuum-pan concentration, but darkens rapidly in storage. If, however, the juice is deionized, as described in the preceding section on raisin sirup, the sirup will retain a light color.

Preservation of Grape Sirup. Grape sirup is best preserved by pasteurization in bottles or enamel-lined cans, accomplished by heating the sirup to 165°F. in sealed containers for 20 min. or by flash heating and canning hot.

The pasteurized sirup should be cooled to room temperature as rapidly as possible, to prevent loss of flavor and color by prolonged heating, since grape sirup rapidly darkens at temperatures above 130°F.

If the concentration of the sirup exceeds 68° Balling, it may usually be stored for several months without danger of fermentation; but crys-

tallization of the dextrose sugar is apt to occur in such highly concentrated sirup.

Separation of Cream of Tartar. Much of the cream of tartar separates as a fine-grained "sand" during concentration, but a considerable proportion crystallizes only very slowly after concentration. In using the sirup for some purposes the presence of the cream of tartar is not objectionable, but generally the sirup should be as nearly free from the crystals as possible.

Yield of Sirup. Grapes yield from 175 to 185 gal. of juice per ton if they are thoroughly crushed and pressed. The pomace can be treated with hot water and pressed to recover most of the residual juice.

The yield of sirup from a given volume of juice varies with the per cent of total dissolved solids (Balling degree) of the juice in accordance with the following formula:

$$G = \frac{b \times s}{B \times S} \times g$$

where G = gallons of sirup, g = gallons of juice, b = Balling degree of juice, s = specific gravity of juice, B = Balling degree of sirup, and S = specific gravity of sirup. By application of this formula it will be found that 100-gal. lots of juices of 18, 19, 20, 21, 22, 23, 24, and 25° Balling will yield 22.5, 23.9, 25.2, 26.6, 28, 29.4, 30.8, and 32.1 gal., respectively, of sirup of 65° Balling.

Apple Concentrate and Sirup. In the past, apple sirup has been used almost exclusively for culinary purposes. If properly prepared, however, it is suitable for soda-fountain use and the preparation of bottled beverages.

Preparing the Juice. If the sirup is to be used for beverage purposes, the apples should be of suitable quality for making sweet cider. For preparing boiled cider for culinary purposes, peels, cores, and apples of all varieties may be used.

The raw material must be sound, carefully sorted, and washed. It must be free of poisonous-spray residues such as DDT, arsenic, lead, and fluosilicates. Crushing and pressing are conducted as in preparing juice for bottling.

The juice should be made as clear as possible before concentration, by the pectic-enzyme method, followed by filtration.

Concentration. Gore has demonstrated that an excellent concentrated cider suitable for beverage purposes can be prepared by the freezing method described earlier in this chapter.

Concentration *in vacuo* at 28- to 29-in. vacuum in a stainless-steel pan heated with water at 120 to 150°F. also yields an excellent product. If concentration is carried beyond 60° Balling, jelling is apt to take place

because of the pectin present in the juice. However, if the juice is previously treated with a pectic enzyme, jelling will not occur.

Probably the best procedure based on present knowledge would be to make a 150-fold essence by the U.S.D.A. Eastern Regional Research Laboratory (Milleville) procedure: concentrate the stripped juice in a low-temperature vacuum concentrator after depectinization, blend with the essence, can, and freeze. Frozen apple concentrate is on the market.

The usual method of making "boiled cider," as previously outlined, is by boiling in the open in a sorghum or maple-sirup pan. This product is often very dark in color and is used in cooking or in making mincemeat.

Preservation. Boiled cider usually keeps without sterilizing. Vacuum-concentrated sirup or that made by the freezing process or by low-temperature vacuum concentration and of 50 to 60° Balling should be pasteurized, to prevent fermentation or molding, or preferably frozen and stored at 0 to −10°F.

Bland Apple Sirup. A table sirup may be prepared from apple juice clarified with pectinol or other pectic enzyme, filtered, neutralized with calcium carbonate, decolorized with activated carbon, filtered, and concentrated *in vacuo* (for further details see paper by Mottern and Morris).

Pear Sirup. Pear sirups similar in composition to concentrated apple juice can be prepared. These possess a rich baked-pear flavor and are suitable for table or culinary use.

Effect of Viscosity on Processing. Irish, Joslyn, and Parcell determined quantitatively the effect of the concentration or Brix degree of sucrose sirups on the rate of heat penetration during pasteurization at 175°F. and the effect of Brix degree on the relative viscosity of the sirups. Table 31 gives their data on relative viscosity versus Brix degree.

TABLE 31. RELATIVE VISCOSITY OF SUCROSE SIRUPS AT ROOM TEMPERATURE

Brix degree	Specific gravity	Relative viscosity
0 (water)	1.000	1.000
10	1.04	1.05
20	1.08	1.15
30	1.13	1.43
40	1.18	2.00
50	1.23	3.10
60	1.29	6.33
70	1.35	49.00

SOURCE: After Irish, Joslyn, and Parcell.

There was a sharp drop in the rate of heat penetration between 60 and 70° Brix, although not so great as the difference in viscosity. In pasteurizing

sirups of different Brix degrees at 175°F., it was found that for sirups in glass containers of the same size it required about 20 min. for the bottle of water to reach 170°F., sirup of 30° Brix about 40 min., 60° Brix about 45 min., and 70° Brix about 58 min.

FRUIT SIRUPS FOR USE IN CARBONATED BEVERAGES

As reported by Cruess and Irish and by Irish, excellent real-fruit carbonated beverages, fruit soda waters, were produced on a pilot scale at the University of California and placed on the market in Berkeley grocery stores and soda fountains in order to test consumer opinion. Response was very good and would indicate that a potential market exists for such products. Full details for preparation of the sirups used in such beverages and for production and preservation of the finished beverages will be found in the *University of California Agricultural Experiment Station Bulletin* 359, *Circular* 313, and a brief outline of preparation of the carbonated drinks from fruit sirups is given in Chapter 12.

Irish has recommended the following procedure for preparing orange sirup for bottlers' use: To 1 gal. of 72° Brix orange concentrate add 5 gal. of 60° Brix simple sugar (cane or beet) sirup and ¼ fl. oz. of terpeneless oil of orange, emulsified. Mix thoroughly. The concentrate should either be freshly made by low-temperature evaporation or should have been held at 0 to −10°F. until used. To prepare a carbonated beverage add 1½ fl. oz. of the sirup to a 6½-oz. soda-water bottle. Then add carbonated water to fill. Seal bottle with Crown cap. Pasteurize at 150°F. for 30 min. Cool rapidly. If the beverage is too low in acidity, add citric acid to the sirup to suit taste of customers.

For lemon-soda sirup Irish recommends that 1 gal. of lemon concentrate of 72° Brix be blended with 20 gal. of 60° Balling simple sugar sirup and ⅔ fl. oz. of emulsified terpeneless lemon oil.

Loganberry, boysenberry, currant, blackberry, and other berry sirups for use in carbonated beverages are made by treating the juices prepared, as described in Chapter 12, with a pectic enzyme to prevent jelling of the sirups, followed by addition of sugar to give sirups of 50° Brix. For grape concentrate for carbonated-beverages concentrate, depectinized, detartrated Concord juice may be concentrated to 65° Brix, using the Milleville essence-recovery procedure and returning the flavor essence to the concentrate. Preserve by freezing. For use in carbonated, bottled beverages add 1 gal. of 60° Brix simple sugar sirup to each gallon of the grape concentrate.

Apple concentrate made by the Milleville essence-recovery procedure, described earlier in this chapter, may be used in preparing bottled carbonated beverages. The juice should be depectinized by enzyme treatment

before concentration. An equal volume of simple sirup may be added to the concentrate before its use in beverages.

In most cases 1½ fl. oz. of any of the foregoing sirups would be used per 6½-oz. soda-water bottle; carbonated water added to fill; bottle crown capped and pasteurized at 150°F. The beverages can also be preserved by use of $\frac{1}{10}$ of 1 per cent of sodium benzoate; but its presence must be declared on the label, and to many consumers the benzoate imparts an off taste.

Fruit-punch Sirup. A number of years ago the Food Technology Department of the University of California prepared on a pilot scale several types of fruit concentrates and sirups and placed them on the local market in order to test consumer reaction. The most successful was a fruit-punch sirup consisting of a blend of red-grape concentrate, orange concentrate, lemon sirup of about 50° Brix made by adding sugar to fresh lemon juice, and pineapple sirup of 50° Brix made by adding sugar to canned pineapple juice. The resulting punch sirup was of about 60° Brix. It was preserved by freezing storage or by flash pasteurization, bottling hot, and cooling the bottled sirup quickly.

It was used at various campus, fraternity, club, and sorority dances and in the home for preparation of a pure-fruit punch. The red-grape concentrate should be made from Concord grapes because they furnish both color and flavor. The sales test was very successful, and there is reason to believe that a good potential market exists for such a product sold in frozen form.

Spoilage. Citrus and other sirups darken by reaction of amino acids and sugars, with evolution of carbon dioxide gas. If the concentration is too low, they may ferment with yeast or may mold unless stored at 0 to −10°F. For further details on darkening see Chapter 20, Packing of Dried Fruits and Vegetables.

Berry Sirups. Berry sirups are used extensively in soda fountains for carbonated drinks and for dressings for ice creams. They should find wider use than is the case at present, for production of carbonated bottled drinks and in the household in the preparation of fruit punch, gelatin desserts, cake fillings, etc.

The berries should be thoroughly ripe, free from mold or fermentation, and should be carefully sorted and washed. Strawberries need not be hulled.

The berries are crushed, heated to about 160°F., pressed, cooled, treated overnight with a pectic enzyme, and the juice filtered. Sugar can then be added to increase the Balling degree to about 60 to 65 for strawberry and raspberry juices. Loganberry, currant, and sour blackberry sirup will often jelly if the sugar concentration exceeds 50° Balling and unless the juice is depectinized by enzyme treatment. Pulpy berry sirups are also made.

If the sirup is to be stored at room temperature, it should be pasteurized in bottles or enamel-lined cans (Chapter 12).

Excellent sirups, more concentrated in flavor and color than those described above, can be made by the freezing process. The Balling degree of the juice should be increased to about 20 to 25 per cent by addition of sugar before freezing, or sugar should be added after the second freezing and centrifuging of unsweetened juice to increase the concentration to about 50° Balling. The added sugar reduces the tendency of the juices to oxidize and change in flavor.

Strawberry sirup is usually deficient in color, but the addition of a small proportion (10 to 20 per cent) of blackberry sirup produces a blend of rich strawberry flavor and of bright red color.

Berries do not yield palatable sirups without the addition of sugar, although they have been concentrated successfully by freezing and *in vacuo* by the Milleville method or Serailian process, in which the volatile flavoring compounds are recovered and returned to the concentrated juice.

Pomegranate Sirup. Pomegranate juice prepared as described in Chapter 12 yields a sirup suitable for soda-fountain and bottling use when sugar is added to increase the Balling degree to about 40. This sirup blends well for beverage purposes with citrus juices. True grenadine sirup should be made from pomegranate juice, but most so-called "grenadine" sirup is a purely synthetic preparation.

Sirups from Dried Fruits. Low-priced dried fruits of sound quality are sometimes used for the preparation of sirups for use in medicines or for the table. The fruit can be extracted with water in any one of several ways.

It can be soaked in water until plump (24 hr.) and then crushed and pressed in the usual manner. The press cake should be soaked and pressed a second time.

The fruit may be heated in several changes of water, and the dilute extract so obtained can be used to extract succeeding lots of fruit until an extract is obtained rich in sugar and requiring very little concentration by boiling. This procedure is very successful with dry prunes, the resulting sirup being satisfactory as a beverage on dilution with water. A sirup of 50° Brix is readily attainable by diffusion of several successive portions of prunes.

An excellent prune concentrate has been prepared by the author experimentally as follows: A prune juice of high quality is first made by series (battery) extraction of dried prunes with water at 160 to 175°F. The resulting juice of 20 to 25° Brix is depectinized by enzyme treatment as described for apple juice in Chapter 12; filtered; concentrated by low-temperature vacuum concentration to 61 to 63° Brix; canned; and preserved by freezing. It is diluted to about 20° Brix with three cans of water to one can of concentrate for serving.

The sugary extracts prepared in any of the above ways must be further concentrated by boiling *in vacuo*. Because of their mild laxative action, sirups from dried prunes or figs are in use in certain pharmaceutical preparations. Incidentally, sirups made from California prunes are much more laxative than fig sirup.

Raisin sirup and sirup from other dried fruits are suitable for table and culinary purposes. The sugary extract from raisins can be neutralized with calcium carbonate, decolorized with vegetable carbon, then treated with exchange resins as previously described, and concentrated *in vacuo* to give a water-white sirup.

Carefully dehydrated berries can be used for the preparation of sirups for soda-fountain use and for bottling purposes.

SIRUP FROM SWEET POTATOES

Oversize, blemished, and misshapen sweet potatoes, according to Gore, often represent 40 per cent or more of the total crop and are usually allowed to go to waste. He has developed a relatively simple process for converting them into a palatable table sirup.

Blanching. The sorted and trimmed potatoes are boiled in three changes of water to remove from the skins soluble materials that would otherwise injure the flavor and color of the sirup.

Cooking. The blanched potatoes are then boiled in water or steamed until soft in order to gelatinize the starch and prepare it for mashing. Water equal to about twice the weight of the potatoes is then added, and the potatoes are stirred until thoroughly broken up and mixed with the water.

Mashing. The temperature of the mixture is then brought to 140°F., and about 1 per cent of finely ground pale barley malt free from sprouts is added and thoroughly mixed with the potatoes. The "mash" is held at 125 to 145°F. (preferably 140°F.) until a drop of filtrate from the mash fails to give a blue coloration when mixed with dilute iodine solution. The mashing period is 20 min. to 1 hr.

The diastase of the barley malt during the mashing process converts the starch of the potatoes into maltose, according to the following reaction:

$$\underset{\text{Starch}}{(C_6H_{10}O_5)x} + H_2O + \text{diastase} = \underset{\text{Maltose}}{xC_{12}H_{22}O_{11}}$$

Dextrins are obtained as intermediate products, and the saccharified mash contains a small amount of dextrin.

Pressing. The wort (sweet liquor) is separated from the pomace by pressing in a rack-and-cloth fruit press.

Clearing the Wort. The wort may be boiled and then filtered in a filter press with infusorial earth.

Concentration. The juice may be concentrated in any one of the sirup-concentrating devices described earlier in this chapter.

Refining. Frequently the sirup possesses an "off" raw flavor. In such cases the partially concentrated sirup should be mixed with a small amount of bone black or vegetable-filter char and about 3 per cent of its weight of infusorial earth, boiled a short time, and filtered. A sirup of neutral flavor is then made by concentrating the refined sirup to the desired density.

Yield. The yield of sirup is equal to about one-third the weight of the raw potatoes used.

Character of the Sirup. If properly prepared, the sirup is of light amber color and of mild but characteristic flavor.

REFERENCES

Berry, J. M., Foliazzo, J. F., and Murdock, D. I.: A rapid method for the presumptive identification of bacteria in concentrated orange juice, *Continental Can Co., Research Dept., Bull.*, February, 1954.

Bissett, O. W., Veldhuis, M. K., and Rushing, N. B.: Effect of heat treatment temperature on the storage life of Valencia orange concentrates, *Food Technol.*, **7**, 258, 1953.

Braverman, J. B. S.: "Citrus Products," Interscience Publishers, Inc., New York, 1949.

Brokaw, C. H.: The role of sanitation in quality control of frozen citrus concentrates, *Food Technol.*, **6**(9), 344, September, 1952.

Buck, R. E., and Mottern, H. H.: Apple sirup by ion exchange process, *Ind. Eng. Chem.*, **37**, 635–639, July, 1945.

Burton, L. V.: High vacuum techniques utilized for drying orange juice, *Food Inds.*, **19**, 617–622, 738, 740, 742, 744, 1947.

Bryden, C. L., and Dickey, G. D.: "Filtration," Reinhold Publishing Corp., New York, 1923.

Charley, V. L. S.: The commercial production of fruit sirups, *Fruit Products J.*, **17**, 72–77, 83, 1937. Also *Ann. Rept. Agr. Hort. Research Sta., Long Ashton, Bristol*, 1936.

Cole, G. M.: Concentrates for lemonade, *Food Technol.*, **9**(1), 38–45, 1955.

Cross, J. A. and Gemmill, A. V.: Revolutionary evaporator raises quality and lowers costs, *Food Inds.*, **20**, 1421–1423, 1948.

Cruess, W. V.: Fruit concentrates and their use, *Fruit Products J.*, **21**, 165–169, 187, 190, 1942.

——— and Gibson, A.: Frozen prune and apple concentrates, *Univ. Calif. Agr. Expt. Sta. Rept.*, 1950. Mimeographed.

———, Glazewski, I. G. A., and Seagrave-Smith, H.: Experiments on frozen citrus juices and sirups, *Fruit Products J.*, **26**(1), 8–10, 25, September, 1946.

——— and Irish, J. H.: Fruit beverage investigations, *Univ. Calif. Agr. Expt. Sta. Bull.* 359, 1923. Out of print.

———, Seagrave-Smith, H., and Glazewski, I. G. A.: Frozen concentrate makes fresh lemonade, *Quick Frozen Foods*, April, 1947.

Felton, G. E.: Use of ion exchangers in by-product recovery from pineapple waste, *Food Technol.*, **3**(2), 40–42, 1949. Describes sirup production.

Flosdorf, E. W.: Drying by sublimation, *Food Inds.*, **17**(1), 92–96, 168–178, January, 1945. Drying from the frozen state.

Golden Citrus Juices boosts plant capacity, *Western Canner and Packer*, July, 1951.

Gore, H. C.: Apple syrup and concentrated cider, *U.S. Dept. Agr. Yearbook*, separate 639, 1914. Freezing process.

Guyer, R. B., Miller, W. M., Bissett, O. W. and Veldhuis, M. K.: Stability of frozen concentrated orange juice. I. The effect of heat treatment on enzyme inactivation and cloud stability, *Food Technol.*, **10**(1), 10–16, January, 1956.

Harper, J. C., and Tappell, A. L.: Freeze drying of food products, chap. 5, pp. 172–232, in E. M. Mrak and G. F. Stewart (eds.), "Advances in Food Research," Academic Press, Inc., New York, 1957.

Hausbrand, E.: "Evaporating, Cooling and Condensing Equipment," Scott, Greenwood & Sons, London, 1923.

Havighorst, C. R.: How orange products are made, *Food Inds.*, **17**(9), 78–84, September, 1945.

Heid, J. L.: Modern technics produce quality citrus products, *Food Inds.*, **17**, 626–629, 1945.

———: Concentrating citrus juices by the vacuum method, *Food Inds.*, **15**(7, 8), May and June, 1943.

——— and Beisel, C. G.: Improved citrus concentrate depends on advanced technique, *Food Inds.*, **20**, 516–519, 1948.

——— and Kelly, E. J.: The concentration and dehydration of citrus juices, *Canner*, **116**(5), 9–13; (6), 13–15; 1953.

High density grape juice concentrate, *Food*, March, 1953.

Irish, J. H.: Fruit juices and fruit juice beverages, *Univ. Calif. Agr. Expt. Sta. Circ.* 313, 1928.

Joslyn, M. A., and Sedky, A.: Effect of heating on the clearing of citrus juices, *Food Research*, **5**, 223–225, 1940.

Kaufman, C. W., and Campbell, H. A.: Some fundamental considerations in the processing of frozen orange concentrate, *Food Technol.*, **3**(12), 396–398, 1950.

Kelly, E. J.: New low-temperature evaporator doubles plant production, *Food Inds.*, **21**, 1386–1389, 1949.

——— and Schwartz, H. W.: Role of the evaporator in the production of frozen concentrates, *Food Technol.*, **9**(7), 335–340, 1955.

MacDowell, L. G., Moore, E. L., and Atkinson, C. G.: U.S. Patent 2,453,109, 1948. On a method of producing citrus concentrates.

Milleville, H. P.: Recovery of natural apple flavors, *Fruit Products J.*, **24**(2), 48–51, October, 1944.

Murdock, D. I., Brokaw, C. H. and Allen, W. E.: Plate type heat exchanger as a source of bacterial contamination in processing frozen concentrated orange juice, *Food Technol.*, **9**(4), 187–190, 1955.

Musco, D., Yanase, K., and Lee, L. J.: Results of University of California studies on quality of sirups made from low-grade raisins, *Food Packer*, November, 1954.

Prosser, D. S., Grierson, W. F., Thor, E., Newhall, W. F., and Samuels, J. K.: Bulk handling of citrus fruit, *Univ. Florida, Agr. Expt. Sta. Bull.* 564, 1955.

Pruthi, J. S., and Girdhari, L.: Studies on technological aspects of manufacture of passion fruit juice and squash, *Chem. Age (India)*, **6**(2), 39–48, 1955.

Richert, P. H.: Darkening of grape products, *Fruit Products J.*, vol. 10, October, 1930.

Riester, D. W., and Ayres, T. B.: Packaging of frozen citrus concentrates, *Food Technol.*, **9**(9), 456–458, 1955.

Rouse, A. H., and Atkins, C. D.: Heat inactivation of pectinesterase in citrus juices, *Food Technol.*, **6**(8), 291, August, 1952.

Roy, W. F., and Russell, H. E.: Concentrated and then quick frozen orange juice retains its vitamin C, *Food Inds.*, **20**, 1764–1766, 1948.

SCHWARTZ, H. W., and PENN, F. E.: Production of orange juice concentrate and powder, *Ind. Eng. Chem.*, **40**, 938–944, 1948.

SERAILIAN, M. K.: U.S. Patent 1,237,962, Aug. 21, 1917.

SMOCK, R. M., and NEUBERT, A. M.: "Apples and Apple Products," Interscience Publishers, Inc., New York, 1950.

STAHL, A. L.: Concentration of citrus juices by freezing, *Proc. Florida State Hort. Soc.*, 1944, pp. 43–45.

STEVENS, J. W., PRITCHETT, D. E., and BAIER, W. E.: Control of enzymatic flocculation of cloud in citrus juices, *Food Technol.*, **6**(12), 469, Dec., 1950.

TRESSLER, D. K., and JOSLYN, M. A.: "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

VELDHUIS, M. K., SCOTT, W. C., and GRIFFITHS, F. P.: Frozen grapefruit, tangerine and limeade concentrates, *Food Technol.*, **9**(4), 198–201, 1955.

WALKER, L. H., and PATTERSON, D. C.: A laboratory fruit-essence recovery unit, *Food Technol.*, **9**(2), 87–90, February, 1955.

WRIGHT, C. E.: Orange concentrate with 95 per cent flavor esters, *Food Eng.*, **27**(2), 70, 71, 207, February, 1955.

CHAPTER 14

PECTIN, JELLIES, AND MARMALADES

The manufacture of jellies and marmalades is one of the oldest and most important of the fruit-products industries and affords a means of utilizing a large amount of sound fruit unsuited to other purposes.

DEFINITIONS

Jelly. Jelly is prepared by boiling fruit with or without water, expressing and straining the juice, adding sugar (sucrose), and concentrating to such consistency that gelatinization takes place on cooling. A perfect jelly is clear, sparkling, transparent, and of attractive color. When removed from the glass, it should retain its form and should quiver, not flow. It should not be sirupy, sticky, or gummy and should retain the flavor and aroma of the original fruit. When cut it should be tender and yet so firm that a sharp edge and smooth, sparkling cut surface remain.

Marmalade. A true fruit marmalade is a clear jelly in which are suspended slices of fruit or peel. Frequently jams are mislabeled as marmalades.

CONSTITUENTS OF JELLY

Three substances are essential to the preparation of a normal fruit jelly. These are pectin, acid, and sugar. Of these, pectin is the most important.

Pectin. It is possible to make a jelly of excellent consistency by combining pectin, acid, sugar, and distilled water in the proper proportions. Fruit juices that are normally deficient in pectin or acid, or both, will make good jelly if these constituents are added. More will be said of pectin later in this chapter.

Acid. Acid is a necessary constituent of fruit jellies. Juices that are deficient in acidity will make good jelly if citric, tartaric, or other suitable acid is added, provided the proper proportions of pectin and sugar are present. The effect of various concentrations of acid on the jelling point will be discussed later.

Sugar. Sugar, the third necessary constituent of fruit jellies, may be in the form of any readily soluble sugar, such as cane sugar, dextrose, levulose,

maltose, etc. Jelly forms when the concentration of the water-sugar-acid-pectin mixture attains a certain minimum value, which is dependent within limits on the proportions of pectin, acid, and sugar.

NATURE OF JELLY

It is probable that the formation of jelly from pectin, acid, and sugar is not a definite stable chemical compound, because if fruit jelly is diluted with warm water the constituents go into solution and can be separated by suitable physical means. Pectin recovered in this manner experimentally has been used in making jelly by again heating it with sugar, acid, and water. This finding tends to disprove Fremy's belief that jelly formation is due to the hydrolysis of pectin to pectic acid by the action of heat and acid. Pectin solutions heated a short time with alkali and then acidified form gels, owing to separation of hydrated pectic acid.

Jelly formation is a colloid phenomenon influenced by pectin concentration, constitution of the pectin, size of the molecule, hydrogen-ion concentration, and sugar concentration.

One plausible explanation of pectin-gel formation considers it a precipitation phenomenon rather than a phenomenon dependent on swelling of a colloid, pectin. According to this explanation, pectin is precipitated by the added sugar, which disturbs the equilibrium previously existing between the water and the pectin. The pectin is precipitated not in the anhydrous condition but as a hydrated colloid that forms a network of fibrils throughout the mass, binding the sugar sirup into a gel. The jelly strength depends on the concentration of the pectin, since obviously with little pectin the network cannot be so dense as with higher concentrations.

Also, the more concentrated the sugar solution, the less water there is for the jelly to support and therefore the stiffer the texture. Acid causes the jelly to be firmer, probably by toughening the fibrils. If the acidity is too low, the fibrils are too weak to support an interfibrillar sirup adequately; consequently the jelly is weak. On the other hand, if the acidity is too high, the jelly "weeps" and may become sirupy. One theory for this phenomenon is that too high acidity causes the fibrils to be too inelastic to maintain the gel structure; another is that it may cause excessive dehydration of the pectin. The texture of pectin is also affected materially by certain salts.

Phaff and Joslyn (1947) state that the action of pectin, sugar, and acid in the formation of jellies can be accounted for by the Kruyt hypothesis of the stabilization of emulsoids by hydration and charge on the particles. Pectin is considered to be a negatively charged hydrophilic colloid which is stabilized by a layer of water surrounding the individual micelles. Jelly formation occurs, according to this hypothesis, when precipitation of the

pectin occurs in ramifying aggregates of micelles in the presence of sugar, which acts as a dehydrating agent, and in the presence of hydrogen ions which act to reduce the negative charge on the pectin. The pectin coalesces in the form of a network of insoluble fibers. Olsen (1934) first suggested this theory, and it has been supported by the work of Joseph, Hinton, and others.

As the power of pectin to form jelly with sugar and acid depends on its molecular size, any treatment that reduces this property tends to reduce its jellying power. Highly purified pectin has a methoxyl (OCH_3) content of about 11 per cent; if the methoxyl content is decreased by any means such as by treatment with alkali, acid, or pectolytic enzyme, its jelly-formation power, usually but not always, decreases more or less proportionately, and according to Phaff and Joslyn, the pectin precipitates out of solution when the methoxyl content of pure pectin is reduced to below 3 to 4 per cent.

Owens and Maclay have found that the maximum pH for jelly formation of purified pectin of 10 to 11 per cent methoxyl content is about pH 3.5, and for pectin reduced to 5 per cent methoxyl content by alkali or acid treatment the maximum pH value for gel formation drops to 2.9.

A second form of pectin jelly is that formed by partially demethoxylated pectin and calcium at relatively low sugar concentration. See a later section in this chapter on this important subject.

More will be said in following paragraphs concerning the roles of pH value (active acidity), nature of the pectin, sugar concentration, pectin concentration, and the presence of certain salts.

Any treatment, as indicated above, that decreases the size of the molecule, such as partial hydrolysis, decreases its jellying strength. Decrease in methoxyl content is usually an index of decrease in molecular size and in jellying power.

PECTIN AND RELATED COMPOUNDS

Since pectin is such an important constituent of jellies, it is desirable that some attention be given the chemical and physical properties of it and its related compounds.

Definitions. A committee of the American Chemical Society in 1927 defined pectic substances as follows: Pectin includes the methylated substances useful in making jelly. Protopectin is the parent substance from which pectin is derived. Pectic acids are the substances formed on complete demethylation and complete or partial carboxylation of pectin.

Phaff and Joslyn have given the proposed revised nomenclature for pectic substances proposed by Kertesz et al. in 1944 as follows:

Pectic substances is a group designation for those complex, colloidal carbohydrate derivatives which occur in or are prepared from plants and contain a large propor-

tion of anhydrogalacturonic acid units which are thought to exist in a chainlike combination. The carboxyl groups of polygalacturonic acids may be partly esterfied by methyl groups and partly or completely neutralized by one or more bases.

Protopectin. The term "protopectin" is applied to the water-insoluble parent pectic substance which occurs in plants and which upon restricted hydrolysis yields pectin or pectinic acids.

Pectinic Acids. The term "pectinic acids" is used for the polygalacturonic acids containing more than a negligible proportion of methyl ester groups. Pectinic acids, under suitable conditions, are capable of forming gels with sugar and acid or, if suitably low in methoxyl content, with certain metallic ions. The salts of pectinic acids are either normal or acid pectinates.

Pectin. The general term "pectin" (or pectins) designates those water-soluble pectinic acids of varying methyl ester content and degree of neutralization which are capable of forming gels with sugar and acid under suitable conditions.

Pectic Acids. The term "pectic acids" is applied to pectic substances mostly composed of colloidal polygalacturonic acids and essentially free of ester groups. The salts of pectic acids are either normal or acid pectates.

Protopectin. Protopectin is abundant in green fruits that have attained full size. During subsequent ripening it is hydrolyzed by enzyme action to pectin, and during rotting or overripening much of the pectin may be further decomposed to form methyl alcohol and pectic acid. Since protopectin is the binding substance between the cells, its conversion to soluble pectin results in loosening of the bond between cells with resultant softening of the fruit tissues. Undoubtedly other changes that cause softening also occur during ripening. The change from protopectin to pectin in plant tissues can be followed microscopically by use of stains, particularly by the use of ruthenium red.

Phaff and Joslyn state that in the cell wall the pectic substances occur in the isotropic intercellular layer known as the middle lamella and in the primary wall of the meristematic and parenchymous tissue cells. Since these substances occur in intimate mixture with or in a matrix of cellulose, some investigators had concluded that the pectic substances were in chemical combination with cellulose and were called pectocelluloses. However, cellulose can be dissolved away by Schweitzer's reagent, leaving the pectic substances and certain other substances as a fine network in the middle lamella; hence if cellulose and the pectic substances are in chemical combination, the union is a very weak one.

Evidently protopectin has a much larger molecular weight than pectin, although, because of its insolubility, this supposition is difficult to verify. The studies of Bonner and of earlier investigators indicate that the pectic substances in the intercellular layer are chiefly in the form of calcium pectate. Bonner found that they have solubilities similar to those of

calcium pectate prepared in vitro. The effect of calcium salts in hardening pickles, ripe olives, tomatoes, and other plant tissues has long been known, but the role of calcium combined with pectic substances as they occur in plant tissues has only been recently shown. Phaff and Joslyn state (1947) that the bulk of the evidence supports the theory that the pectic substances in the intercellular layers occur as insoluble calcium polygalacturonates, including both pectinate and pectates. In fruits protopectin usually undergoes breakdown into less highly polymerized and methoxylated compounds. This transformation had long been known, but the details of the changes were first elucidated by the research of Carré (1922–1927).

Haas and Hill classify the pectic bodies in relation to other carbohydrates as follows:

Monosaccharides	Pentoses ($C_5H_{10}O_5$) arabinose, xylose, rhamnose, etc.
	Hexoses ($C_6H_{12}O_6$) dextrose, levulose, mannose, galactose, etc.
Disaccharides	($C_{12}H_{22}O_{11}$) sucrose, maltose, lactose, etc.
Polysaccharides	Starches ($C_6H_{10}O_5$) starch, dextrin, inulin, glycogen, galactosans, including galactan and paragalactan
	Gums ($C_5H_8O_4$) (*a*) araban, cerosin, pentosans
	(*b*) mucilages, pectic bodies
	Celluloses ($C_6H_{10}O_5$)

Gums, when hydrolyzed, yield galactose and pentoses, such as xylose and arabinose. Pectose (protopectin), when hydrolyzed, yields pectin and, if the hydrolysis is continued, pectic acid, galacturonic acid, and methyl alcohol.

Composition of Pectin. In defining pectin we refer to those bodies in fruit juices which go into colloidal solution in water and are derived from pectose (protopectin) by ripening processes or other form of hydrolysis. Under certain conditions, in the presence of the proper proportions of sugar and acid, they will form jelly.

Methyl alcohol is liberated quantitatively by hydrolysis of the pectin with dilute alkalies, even without heating, and can be estimated by Denige's or Zeizel's methods.

A wide range of combinations of the constituents of pectin is possible, and it is reasonable to assume that there are a number of different pectins in nature, since pectin from different fruits and vegetables varies considerably, not only in its content of CH_3OH, but also in its physical properties, degree of polymerization and esterification, and behavior when used for jellies.

Ehrlich identified the substance to which pectin owes its acid properties. This is galacturonic acid, an isomer of glucuronic acid, and a halfway oxidation product between galactose and mucic acid. Its formula is $C_6H_{10}O_7$, or $COH(CHOH)_4COOH$. Ehrlich also found magnesium and

calcium in his pectin preparations. On the basis of his findings Ehrlich believed pectin to be a complex calcium-magnesium salt of anhydro-arabinogalactose methoxytetragalacturonic acid. He stated that the arabinose is loosely bound and easily split off by hydrolysis but that the galactose is very tightly bound. However, it is now considered that neither arabinose nor galactose is an essential constituent of pectin.

Sucharipa believed that the number of methoxyl groups present in the pectin molecule affects the jellying power of the pectin. Pectin of lower methoxyl content, he states, is also of lower jellying power. The maximum

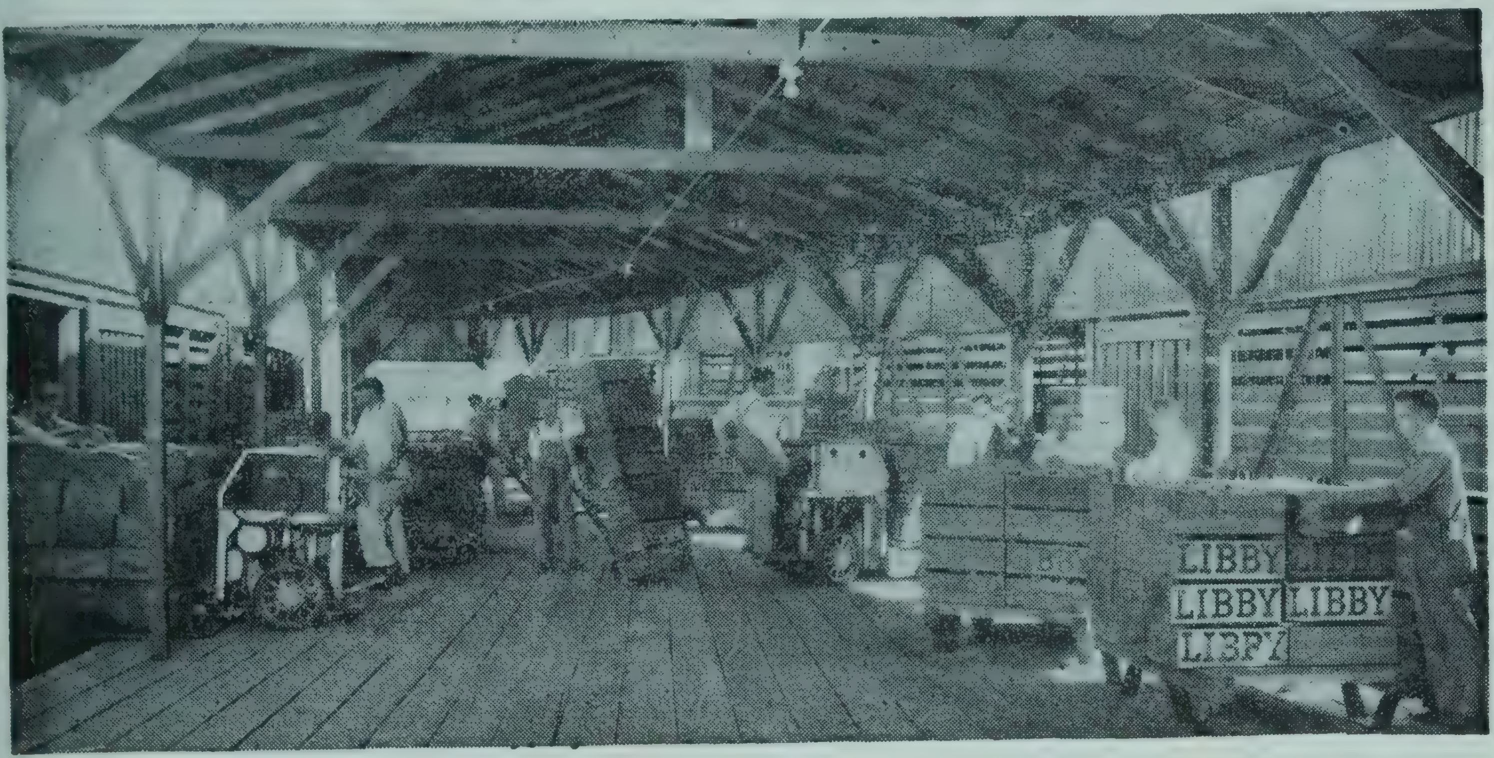


FIG. 70. Receiving lug boxes of fruit at a large cannery. (*Libby, McNeill and Libby.*)

is eight methoxyl groups. Morris states that the formation of pectic acid consists in the replacement in stages of the methoxyl groups by carboxyl groups. The pectin from beet roots differs from that from fruits in that it contains an acetyl group. Naturally occurring pectins may differ in their methoxyl content and in their jellying power.

At any rate it is now well recognized that galacturonic acid is formed on severe acid hydrolysis of pectin or pectic acid. On the basis of this fact pectin may be determined quantitatively as follows: It is first converted into pectic acid by hydrolysis with alkali, followed by precipitation with acid. The pectic acid is then heated in a flask with 12 per cent hydrochloric acid. The carbon dioxide evolved is collected in a Geissler bulb in strong potassium hydroxide or in standard barium hydroxide and determined by weighing the bulb or titrating the excess barium hydroxide.

Enzymes, present in fruits in insoluble form and—in certain roots—in soluble form, have the property of hydrolyzing pectin to pectic acid and alcohol. An enzyme capable of bringing about this reaction is known as "pectinesterase."

Methyl alcohol may be demonstrated in apples that are covered with

paraffin and allowed to stand at 35°C. for a few days, and the same is true of apples placed in water containing toluene. Fruit that has become overripe and has begun to decay also contains methyl alcohol. These facts confirm the presence of pectinase in fruits.

As previously stated, pectin yields, on hydrolysis with dilute alkalies, pectic acid, which, by the addition of a mineral acid, can be precipitated from solutions in which hydrolysis has taken place.

Hydrolysis of apple pectin yields about 95.17 per cent pectic acid and of orange pectin about 94.8 per cent. During saponification the $COCH_3$ grouping is changed to COOH, which causes an increase in weight, approximately equivalent to the difference in the methyl alcohol yield actually obtained and that found by subtracting the per cent of pectic acid obtained from 100.

Pure pectic acid is a white powder, fairly soluble in water and forming a clearer solution than does pectin. It will conduct an electric current and is sour in taste.

Small amounts of electrolytes cause coagulation of pectic acid solutions. Univalent cations are less active than divalent, and divalent in turn are less active than trivalent cations. The differences in precipitation value of these salts are of the same order of magnitude as those for the precipitation of colloidal sulfides.

Pectic acid is precipitated quantitatively as calcium pectate, and this fact is made use of in one method of analyzing pectin solutions.

The relation of pectic acid, pectin, and protopectin is shown by the following diagram:

Protopectin ——→ Pectin (pectic acid methyl ester)

By ripening, boiling in water, alcohol, and dilute acids

By pe[illegible], especially by rotting [illegible]; or by NaOH, $Ca(OH)_2$, a[illegible] $Ba(OH)_2$

By sodium hydroxide, cold

Pectic acid and methyl alcohol

In the above diagram the pectic acid methyl ester of von Fellenberg is an intermediate product between pectin and pectic acid. Branfoot considers that there is a series of these intermediate products, which are designated as pectinic acids.

An excellent and comprehensive treatise on these and other aspects of the properties of pectic substances is that of Kertesz (1951).

Phaff and Joslyn (1947) state that the method used by Schneider and Bock (1937), in which repeated fractionation of the pectin preparation with alcoholic solutions of various concentrations is employed, gives good separation of pectin and araban. By this method pectin free of arabinose

and galactose has been obtained. Both citrus and apple pectins of 92 per cent galacturonic acid and 12 per cent methyl alcohol content were obtained. The sum of the two is greater than 100 because, as noted above, the conversion of the $COCH_3$ groups to COOH results in an increase in weight.

Ehrlich found that an enzyme secreted by *Penicillium ehrlichi* will degrade pectin to galacturonic acid in high yield. The commercial enzyme Pectinol is very satisfactory for this purpose. The galacturonic acid is extracted from the hyrolysate with either ethyl or methyl alcohol. Also it may be precipitated from the reaction mixture as calcium galacturonate. Two forms of d-galacturonic acid are known, and the *l* form has been synthesized.

Phaff and Joslyn indicate that on the basis of published research of various workers on the colloid behavior of pectin, the following properties appear to be well established: (1) the high negative charge of pectin is due almost entirely to the free carboxyl groups; (2) in calcium pectate the calcium is shared between two carboxyl groups of adjacent chains of pectic acid; (3) the micelles of pectin solutions are larger than in most colloid solutions and are in reality gel fragments; (4) pectins appear to be made up of long chains of galacturonic acid residues joined by oxygen bridges, the colloidal micelles being 100 times or more longer than wide; (5) ultracentrifuge measurements show that particle size within a single preparation varies greatly, although these measurements may have been affected by impurities; and (6) pectins are of high molecular weight. Svedberg and Gralen by ultracentrifuge measurements obtained values of 25,000 to 50,000. Owens et al. by intrinsic viscosity measurements got molecular weights of 23,000 to 71,000, while Owens, Miers, and Maclay in a paper on pectin propionates give values for high methoxyl pectins of 61,000 to 115,000. The observed variation in molecular weight of pectins reported by these and other investigators may indicate the existence of pectins of different molecular weights as well as reflect the difficulties involved in such measurements.

Physical Properties of Pectin. Pectin is a reversible colloid; i.e., it may be dissolved in water, precipitated, dried, and redissolved without alteration of its physical properties.

On the addition of water to dry pectin, pastelike lumps are first formed. These finally go into solution, but solution is greatly hastened by heating the mixture and by adding sugar. A solution, clear by transmitted light but cloudy by reflected light, is obtained.

Under the ultramicroscope there will be found in this solution numerous particles in lively motion. These particles vary in size, but all are (ultramicroscopically considered) small.

In addition to alcohol, several metallic salts have the power of precipitating pectin, and at one time it was considered that the precipitates

of pectin with metallic salts were definite chemical compounds. Analyses of the precipitates give varying ratios of salt to pectin, and the present conception of the precipitation is that it is an electrolytic coagulation similar to that which occurs with many other colloids when suitable electrolytes are added.

Preparation of Commercial Pectin. Cull apples, waste citrus peels, waste apple peels and cores, and cull citrus fruits are the usual sources of commercial pectin. This product now has become an important item of commerce and is widely used in the making of jelly. A pectin sirup (Certo) is in common use for preparing jelly in the home. Pectin for commercial use is in powdered form.

Alcohol Precipitation. In 1913 P. R. Boyles was granted a patent upon a process for the preparation of pectin by extraction of the pectin by boiling with water, concentration of the resulting solution by boiling, and precipitation of the pectin from the concentrated solution by the addition of ethyl alcohol. The principal objection to the precipitation of pectin with alcohol is the difficulty of recovering all the alcohol. Propyl alcohol can be used.

Waksman states that in the preparation of a pectin concentrate from apples, the apple pulp (usually dried pomace) is diffused with cold water to extract most of the acid and sugar. The cold water does not dissolve any appreciable proportion of the pectin. The residue after water extraction is then boiled 35 to 40 min. with water containing a small amount (about 0.1 per cent) of tartaric acid. The juice is pressed from the heated pulp and cooled.

A small amount, 1½ to 3 oz. per 100 lb. of extract, of diastasic enzyme from a mold of the *Aspergillus* group (Taka diastase) is added, and the mixture is maintained at 45 to 50°C. (110 to 120°F.) to hydrolyze the starch in solution and thus prevent starch "haze" in the jelly made from pectin extract.

After hydrolysis the solution is filtered and is then concentrated *in vacuo* to a thick sirup, which is preserved by sterilization in bottles. Cans have also been used as containers for pectin concentrates, although there is danger of perforation of the tin plate.

At the Exchange Lemon Products Company plant in Corona, California, several types of pectin are made on a commercial scale from waste lemon peel and cull lemons, the output being over 2 million lb. in the 1951–1952 season. The kinds of pectin produced are (1) rapid- and slow-set pectins for jelly and jam production, (2) pectin for confectioners' use, (3) two types of low methoxyl pectins, (4) three varieties for pharmaceutical and medical applications, and (5) a natural pectin-cellulose form for pharmaceutical purposes.

Joseph and Havighorst (1952) have described in considerable detail the steps followed in producing pectin for preservers and jelly makers' use.

Much of the following discussion is based on their paper. The principal raw material is the ground macerated peel left after pressing of the lemons for juice recovery and distillation with steam for essential oil recovery. This waste material is flumed in water to the pectin department; the fluming acts both to convey the peel and to extract residual citric acid, which assures complete and economical precipitation of the pectin. Citrates interfere with the alum-precipitation method of pectin production used in this plant.

The pectin occurs in the white inner rind of the peel and is present chiefly in the form of protopectin. A revolving reel separates the ground peel from the water used in fluming. The drained peel is conveyed to the pectin-extraction tanks. Water and enough 1 per cent sulfurous acid is added to give a total volume of 3,000 gal. and a pH value of 1.8 to 2.7. The mix is heated with agitation to 95°C. (203°F.) by steam from a perforated cross for 45 min. The heating extracts the pectin and inactivates enzymes. The SO_2 gives the desired optimum pH for extraction and prevents yeast growth later in the process. The hot liquid and peel are next separated by reel, and the peel extracted a second time. During these operations suction fans exhaust the air from the workrooms to remove SO_2 gas, as it is irritating to the lungs and nasal passages of the workmen.

The pectin solution is mixed with infusorial-earth filter aid and filtered through filter presses previously coated with filter aid. The filtrate is cooled to about 30°C. (86°F.) by passage through a cooling tower. The pectin content of the extract is about 0.5 to 0.6 per cent. It is pumped to the precipitation tanks where aluminum chloride is added on the basis of laboratory tests in sufficient amount to react with the pectin. Na_2CO_3 is added to adjust the pH value to 3.8 to 4.2. At about pH 3.5 aluminum hydroxide begins to form and, in the above range, coprecipitates with the pectin to form a fairly firm yellowish-green curd. The curd and liquid are separated by revolving reel, the liquid portion going to waste. The drained curd is next pressed in a cloth-and-rack press similar to that used for the pressing of crushed apples for juice. The pressed curd contains 85 to 90 per cent water.

It is next broken by machine into coarse pieces, and these are cut by machine into shreds about ⅛ in. in diameter. The shreds are mixed with and agitated in a grinder tank with propyl alcohol acidified with HCl. The alcohol and washed curd are separated in a continuous centrifugal at about 1,600 r.p.m., the alcohol going to the recovery system and the curd being returned to a washing tank where it is treated with so-called "first-wash" alcohol consisting of 55 parts alcohol, 6.5 parts HCl, and 38.5 parts water, of about pH 1. The acid leaches the aluminum and sodium salts out of the mix, and the alcohol prevents resolution of the pectin.

The mixture is transferred to special washing and draining drums where

the acid-alcohol liquid is removed by suction filtration. For production of slow-set pectin the washed curd is heated in acidified alcohol (second rinse) for 10 to 20 hr. at 35°C. (95°F.). For rapid-set pectin another schedule is followed in which the curd is washed with 60 per cent alcohol for a short time and then 70 per cent alcohol, HCl solution containing 9 per cent of acid, the pH being 0.5 to 0.6 and the time 15 min. in the rotary washer.

From this point the two types of pectin receive the same treatment. They are rinsed in the rotary washer twice with first-rinse alcohol. Next 75 per cent alcohol with enough ammonia to neutralize any residual HCl is added, and the mixing continued until reaction is completed. The desired pH at this point is 3.6 to 4.2, as pectin is most stable in this range. The liquid is then filtered off; the curd is washed with redistilled alcohol and given a final rinse in 100 per cent alcohol; these rinsings remove practically all the residual NH_4Cl.

The pectin contains about 60 per cent of H_2O at this point. It is dried in a two-stage vacuum drier to 7 to 10 per cent moisture; screened to remove very coarse pieces, which are returned to the extraction line; the finer material is sieved on a 60-mesh screen. The finer material then goes to storage, and the material held by the 60-mesh screen is hammer-milled and rescreened. Air filters recover any very fine pectin powder that escapes from the grinding and screening operations. The pectin powder is analyzed in the laboratory, and small samples are made into jelly, and the jelly carefully tasted and tested for strength, etc. On the basis of these data the batch of 2,400 lb. of pectin is standardized by blending with pure commercial dextrose.

For the preserving trade the usual final product is known as 150-grade pectin, meaning that with water, sugar to give 65 per cent solids, and acid to give the optimum pH, 1 lb. of pectin will give a perfect jelly with 150 lb. of sugar. Pectin of 100 grade is also popular. For use in making marmalade and preserves such as berry preserves, a rapid-set pectin is desired so that jelly will form before the berries or slices of fruit have an opportunity to rise to the top of the glass of preserve or jam. For making jelly, on the other hand, a slow-set pectin is often preferred because after the jelly has firmly but not finally set, handling or jostling of the glasses of jelly is less apt to damage its texture and firmness.

The making of low-methoxyl pectin is considered in the next section. It is a recent commercial development but has attained considerable commercial importance.

Another process is about as follows: The peels from a Citromat juice extractor are ground, mixed with water, and heated high enough to destroy pectic enzymes, and the water is discarded by passage of the mixture over a vibrating screen. The purpose is to remove water-soluble substances such as sugars, acids, and salts. The washed peel is mixed with dilute H_2SO_4,

H_2O, and a little SO_2. The ratio of liquid to peel is about 15:1. The mixture is heated with steam sufficiently to "solubilize" the pectin. Liquid and solids are separated by vibrating screen. The liquid is then filtered twice, once with filter aid and once to remove all traces of filter aid. Aluminum sulfate is added in amount sufficient to precipitate pectin, and a small amount of $CuSO_4$ is added to coagulate the pectin precipitate. Ammonia gas, or NH_4OH, is added to reduce the acidity to pH 3.8. The curd is recovered and dewatered by pressure, ground, and treated with isopropyl alcohol containing HCl to remove Al and Cu. The pectin is washed again with isopropyl alcohol, dried, ground, and standardized.

In another process the dilute filtered crude pectin extract is concentrated *in vacuo* to about 13° Brix; pectin is precipitated at 70 per cent alcohol, drained, hardened in 80 per cent alcohol, pressed, dried and ground, and sifted. [See Havighorst (1945), see also Kertesz (1951) for further information on the commercial production of pectins of various types.]

Low-methoxyl Pectins. According to Woodmansee and Baker (1954), the first report in the literature concerning the formation of nonsugar jellies by reaction of a calcium compound with partially deesterified pectin is that of Braccnnot. In 1831 he found that when he mixed currant and cherry juices a jelly formed on standing. Woodmansee and Baker state that we now know that the enzyme pectinesterase naturally present in one of the juices partially deesterified the pectin of the juice and that calcium naturally present reacted with the free carboxyl groups, allowing a cross linkage of pectin molecules to build up a gel structure. Since the late 1930s interest in partially deesterified, i.e., low-methoxyl, pectins has greatly increased and several commercially produced low-methoxyl pectins are on the market and used commercially for various purposes.

If all the methoxyl groups of pectin are removed, we obtain pectic acid. The low-methoxyl pectins, or pectinic acids, are derivatives of pectin that are intermediate between fully methoxylated pectin and pectic acid, defined as above. They differ from normal pectin in that they will form gels at low sugar concentrations or in the absence of sugar and over a wide range of acidity or pH value. They are acidic in reaction and soluble in water in the absence of or at very low concentrations of bivalent ions. Within a certain range of calcium concentration, which is quite low, they will form gels, but if the concentration of Ca or Mg is too high, they are precipitated in granular form and not as a gel. In the United States, Baker, Woodmansee, and others of the Delaware Agricultural Experiment Station have over the past fifteen years or longer done research and development work on the preparation of low-methoxyl pectins, their properties and utilization; and McCready, Schultz, Owens, Maclay, and others of the U.S.D.A. Western Regional Research Laboratory, Albany, California, have also studied these products very extensively. Consequently, the

chemistry and technology of low-methoxyl pectin preparation, utilization, etc., are quite well established. In addition, commercial producers of pectin have developed much information on these products, some of which has not been published.

The formation of low-methoxyl pectins, or pectinic acids, can be accomplished in one of three ways: (1) by acid treatment at relatively low temperature, low pH value, and for a relatively long period of time, (2) by use of dilute alkali under carefully controlled conditions of pH, temperature, and time, and (3) by use of pectinesterase enzymes, which may be present in the raw material or added from another source. Baker, Woodmansee, and others of the Delaware Station have favored the acid procedure.

Woodmansee and Baker have reviewed the earlier investigations and have reported on methods of making calcium pectinate by acid hydrolysis of the pectin and precipitation of the low-methoxyl pectin with calcium chloride. To make a water-soluble product the pectate was treated either with acidified alcohol, which dissolves out most of the calcium and which prevents dissolving of the pectin; or by treating the calcium pectinate with sodium hexametaphosphate, which sequesters the calcium and thus permits dissolving of the low-methoxyl pectin. They also indicate the low-methoxyl pectins can be recovered from acid-hydrolyzed solutions or gels of low-methoxyl pectins by the aluminum hydroxide coprecipitation method used for pectin recovery, as described earlier in this chapter. Their preferred conditions for acid extraction and demethylation were 50°C. and pH 0.3 to 1.0 for a period required to give the desired methoxyl content.

McCready, Owens, and Maclay point out that the acid method of producing low-methoxyl pectins has the disadvantages that a long period of acid treatment, 12 to 48 hr., and acid-resistant equipment are required. They state that although the enzyme method is rapid and easily controlled, the products appear to require a critical calcium concentration when used for gel formation. They conclude on the basis of their research that demethoxylation with alkali is preferable to the other two methods; but also that it requires close control of operating conditions, notably pH, choice of alkali, and temperature. NaOH at pH values of 10, 11, and 12 at 15°C. or lower demethoxylated the pectin rapidly but tended to lower the gelling power of the pectin unduly unless a relatively low temperature is used. Also during the reaction period hydroxide must be added more or less continuously in order to maintain a constant pH value, because as demethoxylation proceeds, —COOH groups are split off and lower the pH. They found that ammonium hydroxide at pH 10 to 11 was preferable to NaOH, as it was somewhat less rapid in action and maintained the initial pH value because it is a weak alkali and only partially dissociated; and on that account, as some of the OH is neutralized by the acid liberated during demethoxylation, more of the hydroxide dissociates to maintain the pH

value reasonably constant. In the presence of the salts of monovalent and divalent alkali and alkaline earth metals the rate of demethoxylation is markedly increased. Graham and Shepherd (1953) found that the rate was doubled when Na_2SO_4 in 0.2 M concentration was present. Salts of Ca and Mg have a greater effect than Na and K.

Briefly, the method outlined by McCready et al. is as follows: To a 4 per cent pectin solution in a glass-lined kettle was added ammonium hydroxide to give a pH value of 10.5. The temperature was maintained at 15°C. over a period of 3 hr. An equal volume of 95 per cent ethyl alcohol was added to the reaction mixture with enough HCl to adjust the pH value to 5. The mixture was stirred, allowed to stand an hour, and pressed. The press cake was broken up and suspended in 50 per cent alcohol at pH 5.2 in order to remove much of the NH_4Cl. It was then drained and pressed, disintegrated, suspended in 95 per cent alcohol for an hour, pressed, dried *in vacuo* at 65°C. 20 hr., ground by hammer mill, and screened to 100 to 150 mesh. The yield was 90 per cent of theoretical. They state that the aluminum hydroxide method of precipitating the pectin has also been used.

Owens, McCready, and Maclay (1949) have reported on a method differing in some respects from the above (see references).

Graham and Shepherd (1952) of the same laboratory (U.S.D.A. Western Regional Research Laboratory) have reported on a procedure quite similar to that of Owens et al., but stressing the equipment and engineering aspects of the process.

The alcohol precipitation and the aluminum hydroxide coprecipitation methods used in preparing high methoxyl pectins, as described earlier in this chapter, can be used in recovering low-methoxyl pectins from the reaction mixture, but both require large amounts of acidified and neutral alcohol. Propyl alcohol is used, rather than ethyl, as it is tax-free, not potable, and obtainable at reasonable cost in tankcar lots. Alcohol purification of the pectin, however, has one marked advantage over the other methods of recovery and purification: it gives a final product of lower ash content.

Graham and Shepherd recommend that the methoxyl content of low-methoxyl pectins prepared by the ammonium hydroxide method should be 3 to 3.5 per cent on a moisture-free and ash-free basis, ash-corrected for carbonate content. Owens et al. state that at about 2.5 per cent methoxyl content the pectin is so sensitive to calcium that it cannot be used with assurance in fruit juices, or in desert powders when the water to be added contains considerable calcium. Above 3 per cent methoxyl content little difficulty has been encountered with this phenomenon or with syneresis at normal solids content. Baker and Goodwin, on the other hand, give a somewhat wider range of permissible methoxyl content for pectins made by their acid-demethoxylating procedure. For example, they found it possible

to make nonsugar jellies with pectin containing as much as 6.5 per cent methoxyl provided that the proper amount of calcium ion was present. As have others, they point out that the lower the methoxyl content, the less the amount of calcium required for gelation.

Pectic Enzymes. Three classes of pectic enzymes are recognized and have been characterized by various authorities on pectic substances. McCready and Owens (1954) have summarized their properties as follows:

Protopectinase is used to describe the enzyme that converts protopectin into a soluble product. It has also been called pectosinase and protopectinase.

Pectinesterase (PE), or pectinmethylesterase, describes the enzyme that catalyzes the hydrolysis of the ester bonds of pectic substances to yield methyl alcohol and pectic acid. The name pectase does not indicate the nature of the enzyme action and has given way to the more specific names pectinesterase (PE) and pectinmethylesterase.

Polygalacturanase (PG), or pectin-polygalacturanase, is used to describe the enzyme that catalyzes the hydrolysis of glycosidic bonds between the de-esterified galacturonide residues in pectic substances. Pectinase is frequently used to designate the glycosidase and also pectic enzyme mixtures.

Galacturonic acid is formed as an end product.

Uses of Low-methoxyl Pectins. As reported by the investigators of the U.S.D.A. and the Delaware Agricultural Experiment Station, low-methoxyl pectins have many uses. These include low-sugar, low-calorie jellies, gelled milk desserts, puddings and pudding powders, gelled soups, fruit juices, vegetable juices, tomato cocktail, sauces, purées, frozen desserts, canned fruits, and coatings for certain meat products and candied fruits. A formula for a gelled tomato juice (tomato salad) given by McCready et al. (1944) will illustrate the general procedure:

To 100 grams of tomato juice add a dry mix of the following:

Low-methoxyl pectin	0.75 grams
Monocalcium phosphate	0.075 grams
Citric acid	0.50 grams
Sugar	5.00 grams
Salt	1.00 grams
Spices to flavor	

Heat the mixture to boiling with stirring, pour into molds and allow to cool.

In the coating of fish or meats for freezing storage, candied fruit, or other food product, the recommended procedure is to dip the product in a solution of the low-methoxyl pectin or to spray it with such a solution and then dip it in dilute (such as 1 per cent) calcium chloride solution to harden the coating. Then the coating is usually dried by air blast below 80°F.

Shepherd, McCready, and Owens (1951) have found that a sucrose sirup

containing low-methoxyl pectin in the proper ratio to sugar can be drum-dried and the dried product ground to give a stable, very convenient coarse powder for use in preparation of unheated or cooked desserts. A 60° Brix sirup containing low-methoxyl pectin in the ratio of 1 of pectin by weight to 15 of sugar was found to give an excellent dried product. It may be mixed by egg beater with other ingredients such as flavor, etc., in milk or water to give jellied quick desserts of various types.

SUITABILITY OF VARIOUS FRUITS FOR JELLY

Fruits for jelly should contain sufficient acid and pectin to yield a good jelly without the addition of these substances, although often in commercial practice this ideal is not attained. Some fruits contain enough of both pectin and acid for the purpose; some are deficient in one or the other; and some are deficient in both substances.

Of the fruits rich in pectin and acid, crab apples, acid varieties of table apples, loganberries, sour blackberries, currants, lemons, limes, grapefruits, sour varieties of oranges, sour varieties of guavas, Damson plums, most other varieties of sour plums, Labrusca varieties of grapes, sour varieties of cherries, cranberries, and roselle are good examples. Of fruits and vegetables low in acid but rich in pectin, the following may be cited: sweet varieties of cherries, unripe figs, ripe melon, carrots, unripe bananas, and ripe quinces. Fruits and vegetables that are rich in acid but low in pectin are apricots, rhubarb, and most varieties of strawberries. Fruits that may be classed as containing a moderate concentration of both acid and pectin are ripe Vinifera varieties of grapes, ripe blackberries, ripe apples, loquats, and feijoas. Fruits low in both acid and pectin are represented by pomegranates (arils), ripe peaches, ripe figs, and ripe Bartlett pears.

It is customary to blend fruits deficient in acid or pectin, or both, with fruits that have an abundance of the required constituents.

Because it possesses no appreciable flavor of its own, commercially prepared pectin is coming into more general use for the purpose of enriching juices of fruits deficient in this component.

THE PREPARATION OF JELLY

The process of jelly making may be discussed conveniently under several operations, viz., those of boiling the fruit, extraction of the juice, clearing the juice, adding the sugar, boiling, packaging, and sterilizing.

Boiling the Fruit. Most fruits should be boiled for extraction of the juice in order to obtain the maximum yield of juice and pectin, because boiling converts pectose into pectin and softens the fruit tissue.

Very juicy fruits, such as berries, do not require the addition of water

and need only be crushed and heated to the boiling point for 2 or 3 min. For most berries, the shorter the period of boiling, the better the flavor of the resulting jelly. Firm fruits, such as apples and oranges, are cut or crushed and require the addition of water. Citrus fruits are cut in pieces about ⅛ to ¼ in. in thickness.

The length of boiling will vary according to the variety and texture of the fruit. Apples normally require only 20 min. or less, and oranges from 30 to 60 min. The fruit should be heated only long enough to soften it sufficiently to permit thorough extraction of the juice by pressing and not long enough to render it mushy. Fruit that is boiled too long yields a cloudy juice which is very difficult to filter. Boiling converts much of the insoluble protopectin into soluble pectin.

Amount of Added Water. The amount of water that should be added to the fruit should be sufficient only to obtain a good yield of juice and pectin. Juicy fruits require no water; apples require from one-half to an equal volume of water; and citrus fruits, because of the long period of boiling necessary, usually require from two to three volumes of water for each volume of sliced or crushed fruit. If too much water is used, the resulting juice will be too dilute and will require an undue amount of concentrating before jelly can be made from it; if too little water is used, there is danger of scorching the fruit or of obtaining a low yield of juice and jelly. Fruits very rich in pectin, such as currants, loganberries, cranberries, lemons, and Labrusca (Eastern) varieties of grapes, can be extracted to advantage with two or more succeeding lots of water. Frozen-pack berries and plums used for jelly making are handled in much the same manner as the fresh fruits. They should be dumped into the required amount of boiling water while the fruit is still in the frozen condition.

In order to permit operation throughout the year most producers use frozen-pack fruits after the fresh-fruit season ends. Some is purchased from commercial freezers, but much is purchased fresh by the preserver and frozen by him for his own use. It is usually packed in enamel-lined, 30-lb., friction-top egg tins or 50-gal. plastic-lined steel drums. Sugar may or may not be added, but usually is added to berries. A layer of Frodex (dried corn-sirup solids) or sugar is usually placed on top of the fruit to minimize oxidation.

Kettles. The extraction of juice from fruits for the preparation of jelly on a commercial scale is usually accomplished by the use of steam-jacketed kettles, placed on a platform or a floor above the press so that the cooked pulp and juice may be drawn from the kettle by gravity to the press. If a large kettle (50-gal. capacity or more) is used, it should be fitted with a large valve (2 in. or larger) to permit drawing off of the fruit. If the installation is of small size, a tilting kettle is most convenient. Metal tanks holding several hundred gallons of fruit and water are also used. The mixture is heated by steam coils or by direct steam.

Effect of Various Metals. Copper and tin injure the color of fruits if contact at the boiling point is prolonged; hence stainless steel or aluminum is to be preferred for most fruits. The principal objection to steam-jacketed glass-lined equipment is its slow conductance of heat, because of the thickness of the walls. Stainless steel, nickel, and monel metal are the most satisfactory, although costly.

Pressing. The housewife, in preparing juice for jelly making, usually does not press the fruit; she merely places the heated pulp and juice in a cloth jelly bag and allows it to drain, in order to obtain a clear juice.

In the jelly factory a high yield of jelly juice rich in pectin and obtained with a minimum of handling is desired. The use of the rack-and-cloth press has been found in practice to be one of the most desirable means of pressing the juice from the boiled pulp. The hot fruit and juice direct from the kettle are placed in the cloths of the press and pressed as described in Chapter 12.

The Harris press, which consists of vertically arranged, rectangular canvas bags held between heavy stainless-steel plates, is very satisfactory. The bags and plates are held in a heavy steel frame. Pressure is applied horizontally to the ends of the press. Pressing is rapid with high yield of juice low in suspended solids and a compact (dry) press cake. In appearance the press resembles a large filter press. In one large plant in San Jose, California, this press is used very successfully for pressing extracted dried prunes.

Use of Pomace. The press cake may, if desired, be mixed with water in the kettle and heated a second time to obtain the remaining pectin. This is probably not advisable for cheap fruits, such as apple culls and apple waste or citrus-fruit culls, but may become profitable with more costly fruits, such as currants, loganberries, etc.

The press cake (pomace) has some value as stock food and can be fed direct, or it can be dried, stored, and used as needed. It has very little fertilizing value but can be used to improve the texture of heavy soils if mixed with lime in order to prevent formation of harmful concentrations of acid in the soil.

Clearing the Juice. Jelly is most attractive when clear, and most jelly factories now use mechanical filters.

Filtration. In the Food Technology Department laboratory at the University of California a small pulp filter is used successfully, as described in Chapter 12. Filtration is rapid, the filtered juice is fairly clear, and second filtration renders the juice brilliantly clear. This same type of filter was once utilized on a large scale in many commercial jelly factories.

Filter presses are now generally used. The juice is mixed with infusorial earth before filtration. If from $\frac{1}{10}$ to 1 per cent of a good grade of the earth is mixed with the juice, filtration is fairly satisfactory. The earth forms a filtering layer on the press cloths and thereby reduces sliming or clogging.

For the small jelly factory, heavy cloth jelly bags can be used to improve

the clearness of the juice, although it is usually not possible to obtain a brilliantly clear jelly by their use. If a filter aid such as Hy-Flo or Dicalite is added, filter bags yield a clear juice.

Filtration must be accomplished before the addition of sugar, because the latter so increases the viscosity of the juice that filtration becomes extremely slow or impossible. If the juice requires concentration by boiling before the addition of sugar, this should be done before filtering, since boiling causes precipitation of organic matter (probably protein), which should be removed by filtration or other means before sugar is added.

Settling. Some fruit juices can be satisfactorily cleared by settling overnight in vessels 1 to 3 ft. in depth. Shallow tanks should be used because of the relatively slow rate of settling of juices from boiled fruits.

Finings. Numerous experiments have been made (Cruess and McNair) upon the clearing of jelly juices by the use of finings. None of the ordinary finings were very satisfactory, although bentonite and certain kaolin clays give fair clarification.

Centrifuging. Experiments with centrifugal clarifiers have proved that jelly juices can be partially clarified by centrifuging at a high speed, both the Sharpless and De Laval clarifiers being used successfully for the purpose. As much of the coarse pulp as possible should be removed before centrifugal clarification, in order to avoid too rapid clogging of the bowl of the clarifier. This method is rapid and inexpensive in operation. The centrifuged juice should be filtered if very clear jelly is desired.

Addition of Sugar. The housewife usually guesses at the amount of sugar that her jelly juice will require: to juices that she believes rich in pectin she adds an equal or greater volume of sugar, and to juices that she has found by experience to be of poor quality for jelly, less than an equal volume of sugar. Very valuable information can be secured by boiling 200-cc. portions of the juice with 100-, 150-, and 200-gram portions of sugar in a small stew pan and pouring into jelly glasses to cool.

As indicated in a later paragraph, it is customary in most plants to use a standard formula, in so far as volume of juice and weight of sugar are concerned, and to adjust acidity and pectin content of the juice to give a good jelly with this ratio of sugar to juice. Food and drug standards require that not more than 55 parts of sugar to 45 parts of fruit be used. They also permit the addition of a limited amount of corn sugar or of corn sirup or dried corn-sirup solids. Many plants take advantage of this fact. Sugar is now often delivered in bulk by truck or rail and transferred by conveyer or air suction and wide diameter pipe to a storage bin, thus eliminating the handling and storage of bags of sugar. The corn sirup is delivered by tank truck or tank car and stored in bulk in a tank.

In some plants automatic measuring equipment is used to deliver the required, exact volume of juice and weight of sugar for a batch of jelly. In

many plants the mix of juice, pectin, acid, and sugar (also corn sirup if used) is made up in a separate large kettle or stainless-steel tank and is then transferred to a vacuum pan or to several steam-jacketed kettles for boiling to the jelly-finishing point. This markedly reduces labor requirements and standardizes plant operations.

Use of Pectin. Pectin is now very generally added to jelly juices, preserves, and jams to improve their consistency and ensure products of uniform quality and appearance. Since different lots vary greatly in pectin content, it is desirable to know before addition of the sugar the approximate pectin content of the jelly juice. Accurate determination of the pectin content of the juice or fruit by the Wichmann or Carré-Haines method is lengthy and time-consuming. While not very quantitative, the alcohol test for pectin content is very rapid and in the hands of an experienced analyst or jelly maker gives very useful information. Equal volumes, such as 10 cc., of the juice and 95 per cent alcohol, either ethyl or methyl (ethyl denatured with methyl will do), are mixed in a glass beaker or tumbler. A juice rich in pectin will form a jellylike mass, one of medium content forms several lumps of jellylike material, and one poor in pectin a few small pieces of stringy precipitate or no precipitate at all. From such a test an experienced jelly maker can judge fairly closely approximately how much sugar and pectin are required per 100 gal. or other volume of jelly juice. However, it is more customary to add the required amount of pectin necessary to give a good gel and to use a standard ratio of sugar to juice. This is usually 55 lb. of total added sugar to 45 lb. of juice, which is the ratio permitted by food and drug regulations. Account must be taken, of course, of any sugar previously added, as would be the case with frozen-pack fruits frozen with added sugar, Frodex, or other form of sugar. In this regard the alcohol test for pectin must be standardized against factory practice.

Pectin is usually purchased in powdered or granular form. It may be added to the jelly juice by first mixing it with 10 or more parts of dry sugar, adding this mixture slowly with stirring to the heated, but not boiling, jelly juice, continuing heating and stirring until dissolved, and then adding the remainder of the sugar required for the lot, adding also acid if it is required. A temperature of 160 to 170°F. is preferable to 212°F. (boiling) for addition of the pectin and sugar mixture, because at the boiling point the sugar dissolves so much more rapidly than the pectin that it may form lumps that dissolve very slowly.

The alcohol test can be made roughly quantitative by measuring equal volumes of juice and alcohol into a graduated centrifuge tube, mixing well, centrifuging, and reading the volume of the sediment.

The viscosity of the juice varies with the pectin content. Therefore a viscosity test by any standard method may be used as a guide in addition of sugar and pectin.

Acid Determination. The acidity of the juice is nearly as important as its pectin content. Titration of a 10-cc. sample of the juice with $N/10$ sodium hydroxide, using phenolphthalein indicator, is a satisfactory means of determining the acidity. It is generally necessary to dilute the sample with about 100 cc. of distilled water, in order to make observation of the end point accurately. The acidity of the juice should be such that the finished jelly will contain at least 0.5 per cent total acidity, but preferably 0.75 to 1 per cent. Juices of low acidity can be made into jelly without increasing the acidity, but an excessive amount of sugar or boiling will be necessary. It is usually more economical to increase the acidity of such juices by the addition of citric or tartaric acid or by the addition of a juice of high acidity. As stated later, pH value is the real factor involved when one speaks of the relation of acidity to jelly formation.

Some operators determine the pH value of the jelly juice. In one plant if the pH is above 3.3, citric acid is added to reduce it to that value. The acid is usually not added in the dry form, but is first made up in water as a 50 or 25 per cent solution. It may be added before boiling of the juice with sugar or near the end of the boiling period. Theoretically, the latter procedure is preferable since it minimizes hydrolysis of the pectin and prejelling of the batch.

The sugar should be weighed carefully, and the volume of the juice accurately measured. If the volume of the kettle is known, it can be filled to a given height, with actual measurement of the juice avoided. Measurement of the sugar by weight rather than by volume is desirable because of the greater accuracy of the former method.

It is not necessary to heat the sugar before it is added. It must be stirred with the juice in the kettle to avoid sticking and burning. High-quality beet sugar is equally as good as cane sugar for jelly making.

Boiling. Boiling is one of the most important steps in the jelly-making process, as it dissolves the sugar and causes union of the sugar, acid, and pectin to form jelly. It usually causes a coagulation of certain organic compounds that can be skimmed from the surface during boiling, and their removal renders the jelly clearer. Its principal purpose is to increase the concentration of the sugar to the point where jelling will occur.

The boiling operation, while normally a necessary step in jelly making, should be as short as possible. Prolonged boiling results in loss of flavor, injury to color, and hydrolysis of the pectin; consequently it is a frequent cause of jelly failure.

Kettles. Boiling in commercial practice is usually conducted in open steam-jacketed stainless-steel or copper kettles. Stainless steel, nickel, monel metal, and aluminum are preferable to tin, copper, or silver, as they affect color and flavor less. Large deep kettles are less desirable than shallow ones, for the reason that the boiling process must be unduly prolonged in

the deep vessels, with consequent injury to flavor and color. One California factory obtains good results from a stainless-steel kettle holding several hundred gallons.

Skimming. During boiling, the juice should be skimmed if necessary in order to remove coagulated material and should be stirred to cause thorough mixing.

End Point. The boiling is continued until on cooling the product will form a jelly of the desired consistency. The concentration of the mixture

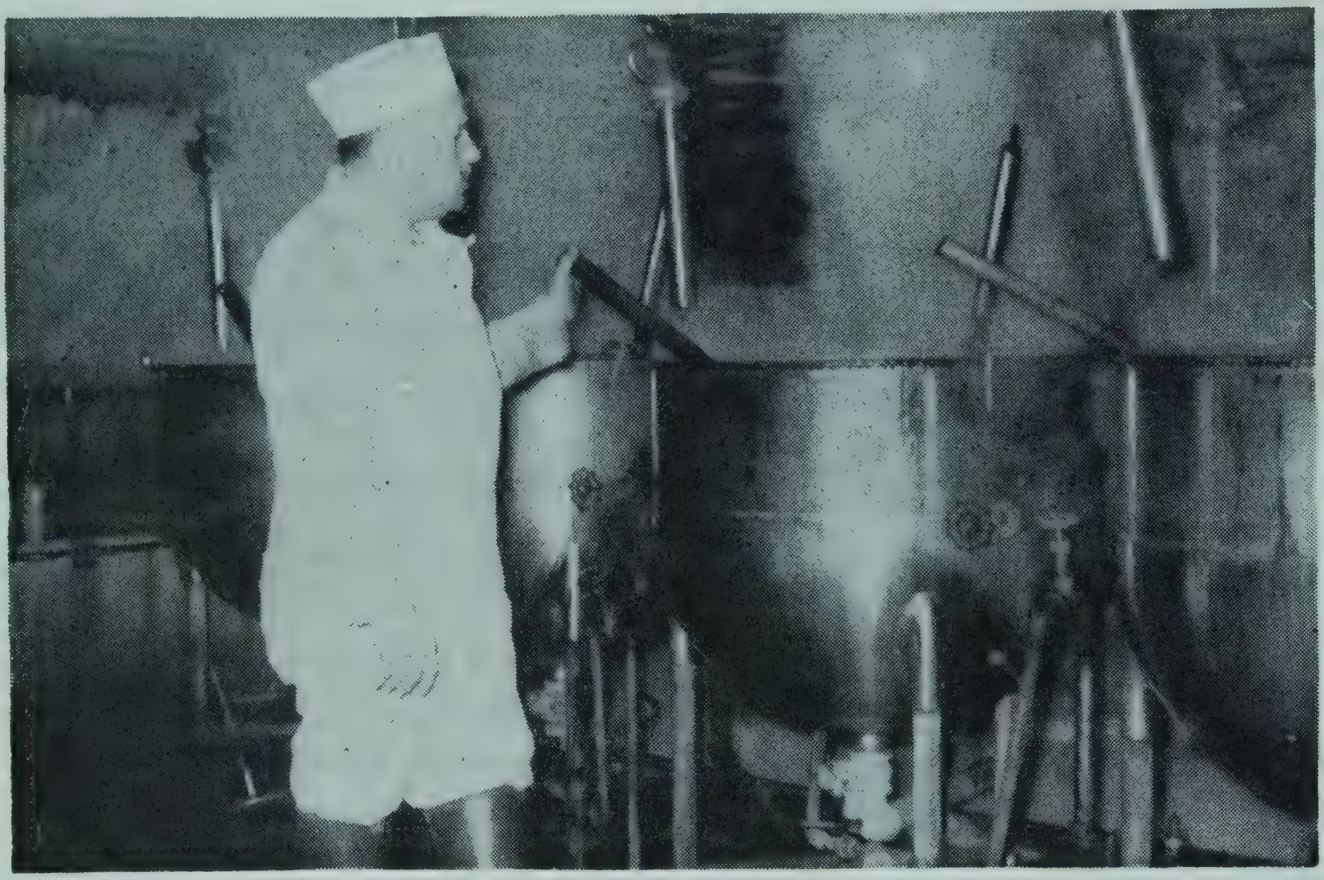


FIG. 71. Cooking jelly. (*Mary Ellen Preserving Co., Berkeley, Calif.*)

when this point is reached will depend upon several factors, viz., the concentration of pectin, the concentration of acid, the ratio of sugar to pectin and acid, and the texture desired. If the jelly is to be shipped long distances and subjected to rough handling, it must be stiffer than if it is to be stored on the pantry shelf at once or to be delivered to local dealers. In general, the finished product should be of the consistency described in the definition of jelly at the beginning of this chapter.

One method of determining the end point is by allowing the liquid to sheet from a wooden paddle or from a large cooking spoon. If it drips from the instrument as a thin sirup, the process is not complete; if it partly congeals and breaks from the paddle or spoon in sheets or forms jellylike sheets on the side of the paddle or spoon, the boiling is considered to be complete. The sheeting test is, however, subject to error because of the personal equation and because of variation in behavior of different lots of juice.

A more accurate method of determining the finishing point is by the use

of a thermometer inserted in the boiling juice (Figure 71). If the juice contains the proper proportions of sugar, acid, and pectin, the boiling point of the liquid at the jelling point will normally be about 7 to 8°F. above the boiling point of water. At sea level this will be at 219 to 220°F. and corresponds to a concentration of 65 to 68 per cent total solids in the jelly after cooling. It is also possible to use a hydrometer test on the hot liquid in order to judge the end point.

However, the quality-control man or the jelly maker in most plants establishes a finishing temperature to suit the customers' requirements and the plant's operating conditions. A refractometer reading is usually also made (see following section).

Jelly manufacturers generally employ an Abbe refractometer for determining the finishing point. A drop or two of the liquid is placed on the prism of the instrument, the prism being cooled by a water jacket. The scale of the instrument is usually graduated in Brix degrees; consequently it is a direct reading instrument, and the use of a table of refractive index versus Brix degree is unnecessary.

In commercial practice the kettle man cooks the mix to the accustomed temperature characteristic of the plant's usual finishing point, shuts off the steam to the kettle, and gives a sample of the hot liquid to the person nearby who is taking refractometer readings. In a few seconds the soluble-solids content (Brix degree) of the sample is known and decision made to package the hot jelly or to cook it further. If it has been overcooked, a small amount of juice may be added and the batch recooked to the desired point.

Preservation. The housewife relies upon high-sugar concentration and an imperfect paraffin seal to prevent molding or fermentation of her jelly. The jelly manfacturer usually packs the jelly near the boiling point, 200°F. or thereabouts, and seals it hot. Such procedure sterilizes the jelly glass and lid, and as the package is hermetically sealed, the product does not mold or ferment.

Flavor Changes. Experiments (Cruess and McNair) indicate that the changes in flavor that take place during the boiling of jelly are brought about both by loss of flavor through evaporation and by hydrolysis or other form of decomposition.

Hydrolysis of Sugar and Pectin. Boiling of the sugar solution in the presence of the fruit acid results in inversion of some of the cane sugar to dextrose and levulose. For this reason a jelly that is boiled for a long period is less liable to develop crystals of sucrose (cane sugar) than is a jelly boiled a short time, assuming that the jelly in both cases is concentrated to the same point.

Pectin is also hydrolyzed by unduly prolonged boiling, and the liquid may fail to gel under such a condition.

Relation of Pectin and Acid to Jellying Point. It was stated above that the end point of the boiling process depends upon the concentration of acid and pectin present in the original juice. Lal Singh, working in the author's laboratory, studied quantitatively the relation of acidity to the jellying point of citrus-fruit juice.

He used dried pectin from oranges, prepared by Bourquellot and Herissy's method, citric acid crystals, distilled water, and cane sugar. A constant amount of pectin, 1.5 grams, was used in each test. The acidity was varied from 0.05 to 4.05 per cent, based on the finished product, and the proportion of sugar was also varied. An excess of water was used to dissolve the pectin, sugar, and acid. The mixture was then concentrated by boiling to exactly 100 grams. The various samples were sealed in jelly glasses, stored, and later examined to determine the sugar concentration at which jelly barely formed with a given acidity.

It was noted that at 0.05 per cent acidity (as citric), 75 grams of sugar per 100 grams of jelly was necessary to form jelly; while at 1.05 per cent acidity, jelly formed when the finished product contained only 53½ grams of sugar per 100 grams of jelly.

Probably the most important variable was the pH value rather than the total acid concentration. See the section on the role of hydrogen concentration.

Similar experiments were made on the effect of pectin content on the jellying point. In general, the results resemble those obtained on variation of the total acidity. Poore obtained a jelly with as little as 0.26 per cent of highly purified citrus pectin, a value somewhat lower than Lal Singh's minimum concentration of pectin for jelly formation. In addition to acid and pectin, as well as sugar, certain salts are important in jelly formation, according to Meyers and Baker. See discussion of jellying of low-methoxyl pectins in an earlier section in this chapter.

Relation of Hydrogen-ion Concentration. L. W. Tarr of the Delaware Experiment Station has made a series of experiments to determine the effect of the hydrogen-ion concentration on the jellying point of mixtures of pectin, water, sugar, and acid. His conclusions are as follows: (1) The formation of fruit jellies cannot be correlated with the total acidity, because the solution may contain buffer substances that reduce the hydrogen-ion concentration without reducing the total acidity as determined by titration. (2) There is a direct relation between the active acidity, or hydrogen-ion concentration, and the formation of jelly. The minimum hydrogen-ion concentration at which jelly formation occurs is pH 3.46, a value that is independent of the nature of the acid used. (3) The presence of neutral salts probably reduces slightly the minimum hydrogen-ion concentration at which jelly will form. (4) Jelly formation occurs irrespective of the amount of pectin present, once the minimum hydrogen-ion con-

centration is reached. However, the quantity of pectin present must be equal to the minimum amount necessary to produce jelly. (5) The character of the jelly is also determined by the hydrogen-ion concentration. It becomes stiffer as the hydrogen-ion concentration increases. Syneresis ("weeping") occurs when the hydrogen-ion concentration is greater than a pH of 3.1. (6) There is a stoichiometrical relation between pectin and the combining power of the acids. (7) Tartaric acid is probably the most effective of the acids commonly present in fruit juices and citric the least effective. (8) The hydrogen-ion concentration of fruit juices depends upon the character of the acids present and upon the buffer action exerted by the juice, pectin itself exerting an appreciable buffer action.

Tarr found that many different acids could be used to cause jellying of mixtures of pectin, acid, sugar, and water and that in all cases the jellying point could be correlated with the hydrogen-ion concentration as noted above. See also the other papers by Tarr, Baker, and others of the Delaware Experiment Station, in the list of references at the end of this chapter. It is possible to make jellies over a wide range of pH value with low-methoxyl pectins since gelling depends on reaction between the pectin and calcium ions.

Use of Commercial Pectin. As previously stated, commercial pectin has come into rather widespread use in the making of jelly. It may be used to reinforce the pectin content of juices of normal fruit content, but it may not be used to "stretch" the juice unduly by addition of excessive amounts of water. Seizures of stretched pectin jellies by food officials have been rather frequent in some localities, and the penalties severe.

Manufacturers of citrus-fruit pectin in California and of apple pectin in New York, Missouri, and elsewhere furnish full and detailed directions for the use of their respective products.

Commercial pectins vary in strength and in rate of setting (rate of jellying). The rate of setting may be controlled by the addition of certain buffer salts. These are usually added to the powdered pectin by the pectin manufacturer. Such salts are sodium citrate, sodium acetate, sodium hydrogen tartrate, disodium hydrogen phosphate, disodium hydrogen citrate, and calcium carbonate. Their presence tends to delay the time of setting, a useful property in some cases, as it permits pouring of the jelly without "graining" caused by partial premature jelly formation in the kettle. Slow-setting pectins are also prepared by the method described in the section on production of citrus pectins. On the other hand, a quick-setting pectin is desired for use in marmalade in order to prevent floating of the fruit.

The jellying power of commercial pectins is expressed in terms of pounds of sugar that will be jellied by 1 lb. of pectin. Thus 1 lb. of a "100-grade pectin" will make a satisfactory jelly with 100 lb. of sugar under certain

specified conditions such as those given by Wilson (see reference list). See formulas given later in this chapter for use of pectin in making jellies on a commercial scale.

Packaging and Preservation. A wide variety of sizes and shapes of containers is used for jellies. Glass is the usual material, although enamel-lined tin cans and special paper containers are also used.

In the household the jelly is usually poured scalding hot into jelly glasses and sealed with melted paraffin. Infection with yeast or mold with consequent spoilage often ensues when this method is used. It is much safer to seal the scalding-hot jelly hermetically in fruit jars or special glasses for home use that may be sealed hermetically, as a paraffin coating is rarely so perfect as to exclude microorganisms.

Filling Machines. Automatic filling machines that measure a definite volume of jelly into each container are in general use in large factories. They greatly reduce the cost of filling as compared with that of hand filling and give more uniform net contents.

Some jellies tend to froth during filling, forming a layer of bubbles on the surface of the glass of hot jelly. Some filling machines are fitted with an automatic skimming device consisting of a suction tube set at such height in the line that it removes bubbles effectively so that they will not interfere with sealing. Frequent samples are taken to check the fill of containers.

Sealing. Jars and glasses in commercial packing are usually tapered in shape and sealed with press-on caps such as the White Vapor Vacuum, Anchor Steriseal tapered finish, and the Owens-Illinois Vapak jar and seal. Also, considerable amounts of jelly and jam are packed in jars or jelly glasses with screw caps, the seal being made by a rubber gasket that rests on the rim of the container.

Other Containers. Small enamel-lined cans are used to some extent for the retail trade, and No. 10 cans for the institutional trade and the military. Wooden tubs or buckets are sometimes used for low-priced jellies for bakers' use. Cans for jellies of deep-red color should be heavily enameled in order to prevent bleaching of the color by reaction with the metal of the tin plate.

Pasteurizing. Containers sealed scalding hot, e.g., 185 to 200°F., need not be pasteurized, as the hot jelly itself will sterilize the container. In some large plants a continuous pasteurizer is used, in which the glasses of jelly are carried by means of a woven wire-cloth conveyer through a tank of water maintained at the pasteurizing temperature. The temperature is held constant by means of a thermostat similar in operation to those described for the regulation of sterilizers for canned foods.

A temperature of 180°F. and a time of 30 min. is usually sufficient. If the jelly is filled hot into the glasses, the pasteurizing time may be shortened; if the glasses are of large size or filled cold, a longer period may become

necessary. Heat-penetration tests should be made by the manufacturer in order to determine the necessary length of the pasteurizing accurately for each size of container.

Cooling. Some continuous pasteurizers are equipped with a device for cooling the jars after pasteurization. This may consist of several tanks of progressively decreasing temperature, through which the jars pass, or of a series of sprays of water of progressively decreasing temperature. If allowed to stand hot for several hours, the jelly will be materially injured in flavor and color.

The most common procedure consists in filling the containers at about 190 to 200°F. The jars or glasses are usually preheated. After filling and capping, the containers are sprayed with hot water to remove jelly adhering to the outside and lids before it has solidified. They are then usually carried through sprays of water of progressively decreasing temperature to cool rapidly to room temperature or slightly above.

PREPARATION OF MARMALADES

A good marmalade should be a jelly with pieces of fruit suspended therein and should not be merely a jam or butter. The principles of jelly making, therefore, apply also to the preparation of marmalade.

Types of Marmalade. English and Scotch marmalades are usually made from the bitter varieties of oranges from Spain, grown principally in the vicinity of Seville and Valencia. In America sweet varieties are used.

Fruit for English Marmalade. The fruit from which the English type of marmalade is produced is high in both acid and pectin, and no difficulty is experienced in obtaining a firm, jellylike marmalade from it.

The fruit may be shipped in boxes or in bulk to the factories in England, or it may be shipped in barrels in brine or in cans sterilized in sliced or shredded form in its own juice. The last-named method is successful but rather costly. The writer has observed the canning of such shredded fruit at Valencia, Spain, for the British trade. One of the largest marmalade producers in England ships the fresh, bitter oranges from Spain to a French port, where the cars are loaded on a freighter and carried to an English port, from which they go by rail to the factory in central England.

Fruit for American Marmalade. In the United States, marmalade is usually made from cull oranges of the shipping varieties, such as the Navel and Valencia. The product is characterized as "sweet marmalade" as distinguished from the bitter English marmalades. The sweet oranges grown in California and Florida for the fresh market are usually somewhat deficient in acid or pectin, or both, when allowed to ripen thoroughly. Therefore it is usually desirable to mix grapefruit or lemons with the oranges, in order to furnish pectin and acid. Marmalade in which grape-

fruit is used is bitter and resembles the English product to a small degree. Those who have been accustomed to the English marmalade prefer the orange-grapefruit type to the orange-lemon type of marmalade, but the average American consumer usually prefers the sweet marmalade.

Deciduous-fruit Marmalades. Marmalades are also made from other fruits, although many so-called "marmalades" are jams rather than marmalades. Various sliced fruits can be mixed with a juice rich in pectin and sugar in preparing a true marmalade, i.e., a jelly in which are suspended pieces of fruit. The famous Bar-le-duc of France is essentially a marmalade prepared from currants.

Preparing the Juice for Marmalade. According to the usual American factory practice in making marmalade, the juice and the sliced fruit are prepared separately and are not mixed until the final boiling of the juice and fruit with sugar.

Slicing. In preparing a marmalade from oranges and lemons, these fruits are mixed in the proportion of about 1 lb. of lemons to 4 to 10 lb. of oranges and sliced about $\frac{3}{16}$ in. thick. Ripe fruit of both varieties is used. In investigations by Lal Singh it was proved that better results are obtained if the ratio of lemons to oranges is increased to equal weights of the two fruits. The flavor is more pleasing and a higher yield of finished product is obtained with this increased proportion of lemons.

Boiling. The sliced fruit is covered with 2 to 3 times its volume of water in a jelly kettle (glass-lined or stainless-steel equipment is to be preferred). The mixture is boiled until the fruit is tender, usually about 1 hr. It is sometimes necessary to add water during boiling to replace that lost by evaporation.

The hot pulp is then pressed in a rack-and-cloth type of press. Heavy cloths or two thicknesses of ordinary press cloths should be used in order to eliminate as much of the fine fruit pulp as possible. A Harris-bag press is also used for this purpose.

Filtration. The juice can be cleared by settling in shallow vessels for 24 hr. or by filtration. Felt or heavy duck bag filters yield a juice which is opalescent but which, nevertheless, produces a marmalade of satisfactory appearance. By use of a filter press it may also be filtered hot after addition of infusorial earth.

Analysis of Juice. The juice should give a good pectin test and should contain at least 1 per cent of acidity expressed as citric acid. It is possible to use the Balling test as a method of factory control in determining the suitability of the juice for marmalade manufacture. If equal weights of lemons and oranges have been used, the juice should test about 6° Balling at 15.5°C. (60°F.), if it is desired that an equal weight of sugar and juice be used. A viscosity test is also useful. A simple procedure consists in noting the time in seconds for a pipette full of the juice to flow from the instru-

ment in comparison with the time required for the flow of water at the same temperature.

Grapefruit equal to 10 to 25 per cent of the weight of oranges used is frequently mixed with the latter fruit in the preparation of juice for bitter marmalade.

Preparing the Sliced Fruit. For the preparation of the usual English marmalade the whole fruit is used, and the juice and peel are not prepared separately, although the method described in the next paragraph is also used. The fruit is very finely shredded by a special machine designed for this purpose.

Three methods of preparing the peel are in use in marmalade factories in California. In one method a band of peeling about 1 in. wide is cut from the orange aroud its greatest circumference. This band is then cut crosswise into very thin slices about $\frac{1}{32}$ in. thick. The pieces possess a "shoe-peg" appearance and give a very attractive marmalade. In one large English factory the peel is removed in three or four segments, which are then cut in thin strips. In another factory the whole fruit is sliced.

In another method some of the whole fruit is sliced very thin and boiled until tender. It is then placed on screens, and the yellow "rag" and pulp are washed from the peels by a spray of water.

In one large factory the whole fruit is chopped finely by means of a mechanically driven mincemeat chopping bowl. As in the English process, no attempt is made in this case to prepare the juice and peel separately. Marmalade prepared according to this method is cloudy and of jamlike rather than jellylike consistency, but its flavor is excellent.

The author prefers the second process for its convenience and for the attractive appearance of the finished marmalade.

Boiling and Packing. In the usual process in California factories, the juice and peel are combined after the latter has been boiled in water until tender. The proportion of peel to juice will depend upon the pectin content of the juice and upon the thickness of the peels. Where the slices are very thin and the juice is rich in pectin, about 5 to 7 per cent of the sliced peels may be added to the juice, together with sugar equal in weight to the juice. If the slices are relatively thick, a larger proportion by weight of peel can be added.

Where the whole chopped or sliced fruit is used without previous separation of the peel and juice, the fruit should be boiled until tender before sugar is added.

Addition of Sugar. The amount of sugar that is required varies greatly with the composition of the juice. As in jelly making, a relatively greater proportion of sugar can be added to juices rich in pectin and acid than to those deficient in one or both of these constituents. Equal weights of juice (i.e., juice and fruit) and sugar is the normal proportion.

Use of Pectin. By addition of the required amount of pectin, results will be more uniform and there will be less danger of the failure of the marmalade to gel. Another great advantage is that the formula can be standardized in respect to ratio of sugar to the other ingredients. Directions are given for the use of pectin in marmalade making later in this chapter. Quick-setting pectin is preferable to the slow-setting in this case as it will gel rapidly enough to prevent undue separation of the peel and jelly.

End Point. The juice, peel, and sugar, or sugar and sliced or chopped whole fruit, are boiled to the jelling point, usually 219 to 220°F., or to the desired total solids content as determined by refractometer. The tests previously described for determining the finishing point of jellies can be used in the case of marmalades. A good marmalade should not be sirupy but should be of jellylike consistency.

Cooling. Marmalade should be allowed to cool partially and to stand a short time to permit absorption of sugar by the peel from the surrounding sirup before the marmalade is placed in the final containers, unless the whole fruit is used without previous separation of juice and peel. If the marmalade is packed boiling hot direct from the jelly kettles, the peels are apt to come to the surface instead of remaining in suspension. However, with use of quick-set pectin separation is not apt to occur. See the commercial formula near the end of the chapter.

Flavoring. The boiling of marmalade removes a great deal of the orange oil from the peels, and the finished product, if made from commercial sweet varieties of oranges, is liable to be lacking in distinctive flavor. A small amount of orange oil or orange extract added to the marmalade and mixed with it thoroughly after the boiling has been completed will usually considerably improve the flavor.

Pasteurizing. The marmalade should be sealed in glass or tin at about 150 to 180°F., as described elsewhere for jellies. Vacuum-sealed containers are best for the purpose, because they reduce the tendency of the product to oxidize. They should be pasteurized in water at 180°F., as described elsewhere for jellies. If filled and sealed at or above 185°F., pasteurization is not necessary.

Other Marmalades. Excellent marmalade can be prepared by combining apple juice rich in pectin and acid with thinly sliced firm peaches, with figs similarly prepared, or with other firm fruits. The juice and sliced fruit can be mixed with sugar and concentrated to the jelling point in the usual manner.

VACUUM CONCENTRATION OF JELLIES AND MARMALADES

Jellies and marmalades cooked in open kettles lose a large proportion of their flavor, aroma, and color by hydrolysis and evaporation, and the

color of red juices becomes brown if the boiling is prolonged or if the jelly is concentrated too far.

The flavor and color of fresh juice are retained better if the jelly is concentrated *in vacuo*. Some commercial manufacturers of jelly and orange marmalade use vacuum pans successfully in regular factory practice.

It is necessary to make frequent tests of the Balling degree, refractive index, or specific gravity of the mixture during boiling. Samples can be drawn from the pan by means of a sampling cock placed near the bottom of the pan. After removal from the vacuum pan the jelly or marmalade can be heated to about 200°F. for filling.

For juices of red color, glass-lined or stainless-steel equipment should be used to avoid injury to the color by contact with corrodible metals.

JELLY AND MARMALADE JUICES

Jelly manufacturers can preserve jelly juice by canning. Shredded oranges and juice are similarly preserved for shipment from Spain to England for the preparation of marmalade. The same method could be employed to advantage in the production, preservation, and sale of jelly juices and marmalade juice for the use of housewives in making jelly and marmalade in the home.

Semicommercial quantities of these products have been prepared in the Food Technology Department laboratory of the University of California and offered for sale to the local public, with very encouraging results. Citrus-fruit juices were canned; other juices were bottled, because cans did not withstand the action of the juice. Probably Type L cold-rolled-plate double-enameled cans would hold the juices satisfactorily.

For the use of housewives the juices must be partially concentrated before canning, or pectin and acid added in order that there may be no difficulty in obtaining good jelly or marmalade. No sugar need be added to the juices at the time of canning.

USE OF DRIED FRUITS IN PREPARATION OF JELLIES AND MARMALADES

Large quantities of dried apple peels and cores from evaporating plants and of dried pomace from apple cider and vinegar factories have been used in the commercial manufacture of cheap jellies for bakers' use. The apple juice is prepared by soaking the dried material overnight, followed by boiling, pressing, and filtering as for the preparation of juice from the fresh fruit. It is then usually combined with berry juice or red-grape juice, or artificial flavor and color are added.

Oranges and lemons can be dried and used for the production of marma-

lade and jelly, and loganberries have been dried in prune evaporators and used for jelly making. The dehydration of these and other fruits does not materially impair their jellying quality, although there is some change in flavor and slight darkening of the color.

FROZEN-PACK FRUITS

Large amounts of frozen fruits, principally berries, are used by jelly and jam makers. The fruit is frozen in 50-gal. plastic-lined barrels or 30-lb. cans or cellophane-lined cartons without sugar, or with 5 or 6 lb. of fruit to 1 lb. of sugar. These fruits are used in much the same manner as the fresh.

CAUSES FOR FAILURE IN JELLY MAKING

Too Much Sugar. The usual cause for failure is the addition to the juice of too much sugar in proportion to the pectin and acid of the juice. Firm jelly can be obtained by properly adjusting the proportion of sugar to the pectin and acid as previously determined by the alcohol test for pectin and by titration of the acidity or determination of pH value.

Prolonged Boiling. Too prolonged boiling results in the hydrolysis of the pectin and in the formation of a sirupy caramelized mass. The juice and sugar should be concentrated to the jellying point as rapidly as possible in order to avoid hydrolysis of the pectin.

Crystals. At ordinary temperatures jelly may develop sugar crystals if the concentration of the finished product exceeds 70° Balling. During the normal boiling of jelly, some of the cane sugar is hydrolyzed to dextrose and levulose, which exhibit less tendency than cane sugar to crystallize.

Crystals of cream of tartar form in grape jelly, but this tendency can be reduced if before the addition of sugar the juice is concentrated by boiling and allowed to deposit its excess cream of tartar in storage. It may also be diluted with water and fortified with commercially prepared pectin or with other fruit juices to the point where crystallization does not occur when jelly is prepared.

FORMULAS

Generally the producer will be able to make satisfactory jellies and marmalades if the principles and procedures previously described in this chapter are followed. Many recipes and formulas are to be found in government and experiment-station bulletins and circulars, and pectin manufacturers have published booklets giving directions and formulas for the use of their products. Several formulas or recipes only will be given here

to serve as illustrations. See also formulas for use of commercial pectin at the end of this chapter.

Berry Jelly without Added Pectin. Use sour berries such as loganberries, currants, or sour varieties of blackberries. Crush. Heat to boiling in their own juice for about 3 min. Press. Filter.

Test pectin content of the juice by mixing 1 spoonful of the juice with an equal volume of 95 per cent grain alcohol. If the mixture forms a stiff jelly, add 1 lb. of sugar to each pint of juice; if a soft jellylike mass forms, use about 3/4 lb. of sugar per pint of juice; and if small separate lumps of a pectin precipitate form, use 1/2 lb. or less of sugar per pint of juice. Heat slowly, and stir until the sugar dissolves. Boil rapidly until a boiling point of 219 to 220°F. is reached. If jelly is made on a small scale, pour into glasses and seal; if on a large scale, fill at 185 to 190°F. in heated jars, and seal. Most commercial jelly is made with added pectin. See formulas near the end of the chapter.

Apple Jelly without Added Pectin. Use sour fruit. Crush or slice. Add water to cover. Boil 20 min. Press. Filter. Test for pectin and proceed as for berry jelly.

Marmalade from Sweet Oranges and Lemons without Added Pectin. Use equal weights of lemons and oranges. Slice about 1/8 in. thick. Add about three volumes of water. Boil 1 hr. Press. Strain to remove coarse pulp. Filter. Determine Balling degree, and make necessary temperature correction. If Balling is above or below 6°, add water or concentrate by boiling, as the case requires, until this Balling is approximately attained. Cut and discard the ends from oranges. Slice the remainder of the orange into very thin pieces. Boil in water until tender. Drain off the juice, but do not press the fruit. Wash the cooked shreds on a screen under a vigorous jet of water to remove fine pulp. Combine the residual peel with the juice prepared from the oranges and lemons above, in the proportion of about 1 lb. of sliced peels to 10 pt. of juice.

If the juice exhibits a good pectin test, add an equal weight of sugar and concentrate to the jelling point as directed for berry jellies. Allow to stand for about 30 min. to permit equalization of the sugar in the peels. Pack into glass or tin containers at about 150 to 170°F. and seal. Pasteurize as directed for berry jellies.

FORMULAS FOR USE OF COMMERCIAL PECTIN

Jelly with Added Pectin. Juices for jelly making are prepared as outlined earlier in this chapter; i.e., by slicing or crushing, adding water to firm fruits such as apples, plums, and citrus, cooking to extract the pectin, pressing, filtering, and testing the juice for total acidity, pectin content, Brix degree, and perhaps pH value.

The California Fruit Growers Exchange (also known as Sunkist Growers) has given the following general directions for making jelly of such juices with the addition of pectin and citric acid: Measure or weigh the fruit juice into the jelly kettle and turn on the steam (see below). Thoroughly mix the suggested amount of slow-set citrus pectin specified in the formula with eight times its weight of sugar and make allowance for this amount of sugar in use of the total amount specified in the formula. Heat the juice to 160 to 180°F. and stir in the sugar-pectin mixture slowly. Then bring to a brisk boil and continue boiling until all the pectin is dissolved. Add the remainder of the sugar and cook to the gelling point, usually to 65 per cent soluble solids determined by refractometer or, according to the manufacturer of pectin mentioned above, to about 220°F. Then add the dissolved specified amount of citric acid. This solution consists of citric acid and water in the ratio of 1 lb. of the acid crystals to 1 pt. of water. It is called "standard fruit acid solution" in the formula. The pectin should be of the slow-set variety.

For loganberry, guava, and pomegranate juices, the California Fruit Growers Exchange recommends the following formula:

Fruit jelly juice	82 lb.
100-grade, slow-set citrus pectin	10–12 oz.
Sugar	100 lb.
Standard fruit acid solution	8 fl. oz.

Cook to 220°F. at or near sea level or to 8°F. above the boiling point of water at a specific locality. Yield: approximately 163 lb. of jelly of 65 per cent soluble solids. Fill hot, above 190°F., cap, wash, and cool, as previously outlined.

If the juice is made from fruit packed and frozen with sugar as, for example, loganberries packed with 2 parts of sugar by weight to 1 part by weight of berries (a so-called 2-plus-1 pack), the formula must be considerably modified in order to allow for the sugar added at the time of freezing. The following formula of the California Fruit Growers Exchange illustrates this situation:

Water	About 4 gals. or 35 lb.
100-grade citrus pectin, slow-set	10–12 oz.
Juice from 2-plus-1 fruit	137 lb.
Sugar	45 lb.
Standard fruit acid solution	8 fl. oz.

First dissolve the pectin with eight times its weight of sugar in the heated water in about the same manner as directed in the preceding formula. Not until then is the juice added. Next add the remainder of the sugar and cook the mixture to 65 per cent soluble solids (220°F.); pour into glasses hot, above 190°F., and cap the glasses. They may then be washed

with sprays of hot water and cooled with sprays of tempered and finally cold water, as previously outlined. Yield: approximately 163 lb. of jelly.

With fruits that are of higher pectin content than those given in the foregoing formulas, less pectin need be used, and with those of lower pectin content, more pectin will be needed. A similar consideration applies to the addition of acid. Also, since 150-grade pectin is in common use, the formulas will require only about two-thirds as much of this pectin as of the 100 grade. Formulas using apple pectin are available from manufacturers.

Orange Marmalade with Added Pectin. The following formula is one given by the California Fruit Growers Exchange "Preservers Handbook," 1941.

Wash 38½ lb. of oranges and 8½ lb. of lemons thoroughly. The fruit is then cut in half, and the juice reamed out as in preparing juice for canning or freezing. The juice is then strained through cheesecloth or sieve to remove seeds and coarse particles, and the juices are mixed.

The peels of both fruits are sliced very thin and covered in a kettle with about 3 gal. of water. They are boiled until thoroughly softened; if not cooked sufficiently, the pieces will become very tough in the marmalade. During cooking, water is added to replace that lost by evaporation.

Discard the water from the thoroughly cooked peel. Add the same amount of fresh water as that discarded; also add the fresh juice prepared above. Next, 12 oz. of 100-grade, rapid-set citrus pectin is mixed with 8 lb. of sugar. The mixed fruit peel and juice is heated to 180°F., and the pectin and sugar mixture is stirred in slowly. Heating and stirring are continued until the pectin dissolves completely. The remainder of the sugar, 92 lb., is next added, and the mix is boiled to 220 to 221°F. at sea level or to about 8 to 9°F. above the boiling point of water at the factory. The steam is then turned off, and the marmalade allowed to stand a few minutes to permit steam bubbles to come to the surface. The acid solution, 5½ fl. oz., or 168 cc., of standard acid solution (consisting of 1 lb. of acid crystals, citric, per pint of water) is added, mixed in well, and the marmalade filled into glasses at or above 190°F. Seal glasses, wash, and cool as previously described. Yield: approximately 152 lb. of marmalade at 68 per cent soluble solids.

By way of summary, the ingredients of the formula are: water, about 3 gal., or 25 lb.; oranges, 38½ lb.; lemons, 8½ lb.; 100-grade citrus pectin, 12 oz. or equivalent amount of 150 grade (rapid-set); sugar, 100 lb.; and standard citric acid solution (1 lb. dissolved in 1 pt. of water), 5½ fl. oz., or 168 cc. Formulas using apple pectin are available from manufacturers.

QUALITY CONTROL

In so far as the inspection of the raw fruit is concerned, berries present the most serious problem for the field department because of the extreme

perishability of these fruits and their tendency to mold; this is especially true of strawberries. Very critical sorting must be followed in order to prevent moldy berries entering the processing department. Many operators of preserving plants buy much of the fresh fruit needed for the year's operations and freeze it and store it at 0 to −10°F. until needed; but they may also buy large quantities of frozen fruits from commercial freezing establishments. In this case it is customary to purchase on U.S.D.A. grade, so that, for example, the frozen fruit shall be of U.S. Grade A or at least Grade B. Many large freezing establishments operate under the U.S.D.A., Agricultural Marketing Administration, Processed Food Products Inspection Service, and each lot to be frozen receives a certificate denoting its U.S. grade. In this regard a very important laboratory determination is a count of mold filaments and other microorganisms by microscope. It is customary in many preserving plants to repeat the microscopical examination of the frozen fruits before they are used in the plant.

Other examinations are semiquantitative estimation of pectin content of the fruit (fresh or frozen), its total acidity and perhaps its pH value, the refractive index or Brix degree of a sample of its juice for soluble-solids content, and organoleptic examination of samples for flavor, color, odor, and general quality. One large California company makes the following observations on each lot of frozen fruit after a sample is thawed: presence of stems, leaves, and bracts and of other foreign material; depth of color; browning by oxidation; percentage of light-colored or green fruit; overripe or mushy fruit; moldy specimens; mechanically damaged fruit; soluble solids in the sirup formed during freezing and thawing; soluble solids in the fruit; acidity and pH value; flavor and odor.

In the purchase of fresh fruit another plant's field department examines the fresh fruit before picking and after it is packed in the boxes or crates for evidence of mold, scab, hail damage, insects such as thrips on berries, pit burn of flesh around pit cavity in apricots and freestone peaches, pH value of a sample of juice, and its soluble-solids content by pocket refractometer. Firm-ripe fruit is preferred to that which is "dead ripe."

In most plants a laboratory assistant, who may not be a college graduate but who is intelligent and dependable, secures frequent samples from the kettles or vacuum pan toward the end of each cook and examines them by refractometer for soluble-solids content. The readings are immediately given by sign or spoken word to the one who is operating the kettle or pan. In this manner overcooking (cooking to too high a final soluble-solids content) or undercooking is rare; or if a lot is cooked too far, it can be blended with another lot before packaging in order to maintain a uniform soluble-solids content in the finished product. Frequent vacuum readings are taken in the laboratory on samples of the containers of packed and cooled product. The texture, flavor, color, and soluble-solids content by

refractometer, net contents by weight, and pH value are other determinations made. One producer in California desires that his jellies have 65 per cent soluble solids and his jams, preserves, and marmalade 68 per cent soluble solids determined by refractometer; and a pH value of 3.4 to 3.5 for jellies and 3.6 for other products.

Firmness of jelly and marmalade may be gauged simply by observing its behavior on removal to a plate (how much it sags, how it cuts with a spoon or behaves when pressed gently with the finger), or a quantitative measurement of texture and firmness may be made with one of several different jelly testers. One of the earlier instruments, and one that is still in common use, is the Tarr-Baker tester, first described by Tarr in 1926 (see references at the end of the chapter). A force is applied to the surface of the jelly through the piston of a syringe actuated by air compressed by a heavy liquid, and the pressure at which breaking of the surface of the jelly occurs is measured and recorded. Another widely used instrument is the Ridgelimeter of Cox and Higby of the California Fruit Growers Exchange (Sunkist Growers) research department, described by them in 1944 (see references). The jellies are poured into glasses of specified size and design to a depth of 3.125 in. and allowed to gel and age under specified conditions. The sample of jelly is then turned out, and the percentage of sag ("flattening out") is measured by micrometer screw at 2 min. Other jelly testers are the B.A.R. tester of Campbell, 1923 and 1938, the Rigidometer of Owens and Maclay, 1946, and the Lampitt and Money tester, 1936 and 1939. For further details of such measurements see Olliver (1950) and Kertesz (1951), as listed in the references.

REFERENCES

Baier, W. E., and Wilson, C. W.: Citrus pectates: properties, manufacture and uses, *Ind. Eng. Chem.*, **33**, 287, 291, 1941.

Baker, G. L.: Methods of regulating the methoxyl content of pectins, *Fruit Products J.*, **22**(1), 10–12, September, 1942.

———: Improved Delaware jelly strength tester, *Fruit Products J.*, **17**(11), 329–331, July, 1938.

——— and Goodwin, M. W.: Effect of methyl ester content upon gel characteristics, *Delaware Agr. Expt. Sta. Bull.* 246, January, 1944.

——— and ———: Viscosity of pectin solutions as affected by metallic salts and pH, *Delaware Agr. Expt. Sta. Bull.* 216, 1939.

——— and Woodmansee, C. W.: Grading pectins, *Delaware Agr. Expt. Sta. Bull.* 272 (*Tech. Bull.* 40), March, 1948.

Boyles, P. R.: A process for preparing jelly base, U.S. Patent 1,067,714, 1912.

Braverman, J. B. S.: "Citrus Products," Interscience Publishers, Inc., New York, 1949.

California Fruit Growers Exchange (Sunkist Growers): "Preservers' Handbook," Ontario, Calif., 1945.

Carré, M. H.: The relation of pectose and pectin in apple tissue, *Biochem. J.*, **19**, 257, 1927.

Central Food Technological Research Institute: "Fruit and Vegetable Preservation Industry of India," Mysore, India, 1956.

Cruess, W. V., and Singh, Lal: Marmalade juice and jelly juice from citrus fruits, *Univ. Calif. Expt. Sta. Circ.* 243, 1922.

Deuel, H., Solms, J., and Altermatt, H.: The pectic substances and their properties (Die Pekinstoffe und Ihre Eigenschaften), *Vierteljahrsschr. Naturforsch. Ges. Zürich*, **98**, 49–86, 1953.

"Directions for Use of Apple Pectin," Speas Manufacturing Company, Kansas City, Mo., 1937. Nutrl-Jel.

Fellers, C. R.: The extraction of apple juices in the manufacture of jelly, *Mass. Agr. Expt. Sta. Tech. Bull.* 15, 1928.

Graham, R. P., and Shepherd, A. D.: Pilot plant production of low methoxyl pectin from citrus peel, *Agr. and Food Chem.*, **1**(16), 993–1001, Oct. 28, 1953.

Havighorst, C. R.: Orange products, *Food Inds.*, **17**, 1022–1027, September, 1945.

Joseph, G. H., and Havighorst, C. R.: Engineering quality pectins, *Food Eng.*, **24**, 87–89, 160–162, 134–137, November, 1952.

Joslyn, M. A., and Phaff, H. J.: The pectic substances, *Wallerstein Revs.*, **10**(29), 39–56, 1947; **10**(30), 133–148, 1947.

Kertesz, Z. I.: "The Pectic Substances," Interscience Publishers, Inc., New York, 1951.

———: Pectic enzymes, *Food Research*, **3**, 481–487, 1938.

McCready, R. M., and Owens, H. S.: Pectin, a product of citrus waste, *Econ. Botany*, **8**(1), 29–47, January–March, 1954.

Meyers, P. B., and Baker, G. L.: The role of pectin in jelly making, *Delaware Agr. Expt. Sta., Bull.* 149, 1927.

——— and ———: The role of salts in jelly making, *Delaware Agr. Expt. Sta. Bull.* 144, 1926.

Morris, T. N.: "Principles of Fruit Preservation," chaps. 1–3, Chapman & Hall, Ltd., London, 1933.

Mottern, H. H., and Hills, C. H.: Low ester pectin from apple pomace, *Ind. Eng. Chem.*, **38**(11), 1133–1156, 1946.

Nanji, D. R., and Norman, A. G.: Pectin, *J. Soc. Chem. Ind. (London)*, **45**, 337–40T, 1926.

Newbold, R. P., and Joslyn, M. A.: Chemistry of analytically important pectic acids, *J. Assoc. Offic. Agr. Chemists*, November, 1952, pp. 873–916.

Olliver, M.: Factors affecting the jelly grading of pectin, *Food Technol.*, **4**(9), 370–375, 1950.

Owens, H. S., Lotzkar, H., Schultz, T. H., and Maclay, W. D.: Shape and size of pectinic acid molecules deduced from viscosometric measurements, *J. Amer. Chem. Soc.*, **68**, 1628–1630, August, 1946.

———, Porter, O., and Maclay, W. D.: New device for grading pectins, *Food Inds.*, **19**, 606–608, 746, 748, 750, 1947.

Pitman, G. A., and Cruess, W. V.: Hydrolysis of pectin by various microorganisms, *Ind. Eng. Chem.*, **21**(12), December, 1929.

Poore, H. D.: Citrus pectin, *U.S. Dept. Agr. Bull.* 1323, 1925.

Schultz, T. H., Owens, H. S., and Maclay, W. D.: Pectinate films, *J. Colloid Sci.*, **3**(1), 53–62, 1948.

Singh, Lal: Study of the factors of jelly making, *Canning Age*, June–August, 1922.

Sucharipa, R.: "Die Pektinstoffe," Serger and Hempel, Brunswick (Braunschweig), Germany, 1925.

Tarr, L. W.: Jelly strength measurements, *Delaware Agr. Expt. Sta. Bull.* 142, 1926.

———: Fruit jellies, *Delaware Agr. Expt. Sta. Bull.* 134 (*Tech. Ser. Bull.* 2), 1923. The role of acid.

TARR, L. W., and BAKER, G. L.: The role of sugar in fruit jellies, *Delaware Agr. Expt. Sta. Bull.* 136, 1924.

VON FELLENBERG, T.: Zur Kenntnis des Pectins, *Mitt. Lebensm. Hyg.*, **5**(4), 1914.

WILSON, C. P.: Relation of chemistry to the citrus products industry, *Ind. Eng. Chem.*, **20**, 1302, 1928. Also, Manufacture of pectin, *Ind. Eng. Chem.*, **17**, 1065–1068, 1925.

WOODMANSEE, C. W., and BAKER, G. L.: The preparation of pecinates and the effect of the degree of esterfication on their gel properties, *Delaware Agr. Expt. Sta. Tech. Bull.* 305, April, 1954.

CHAPTER 15

FRUIT JAMS, BUTTERS, PRESERVES, AND CONFECTIONS

Fruit jams, butters, and preserves are very generally used throughout the civilized world. The people of the British Empire are probably the most important manufacturers and consumers of jams; France is noted for preserved and candied fruits of high quality; China produces preserved ginger root and candied fruits, which are well-known articles of world commerce; and India is famous for a fruit relish known as "mango chutney."

Housewives pride themselves upon their preserves and jams, and probably a greater quantity of fruit is used for these purposes in the home than is used in the factory production of jams and preserves.

DEFINITIONS

The definitions given below conform to the usual conceptions of the products in question.

Jam. Jam is prepared by boiling the whole fruit pulp with sugar (sucrose) to a moderately thick consistency without retaining the shape of the fruit. The United States government pure food regulations require the use of not less than 45 lb. of fruit to each 55 lb. of sugar. In England a jam is usually considered to consist of fruit pulp cooked with sugar to a jelly consistency.

Fruit Butter. This product is prepared by boiling the screened fruit pulp with or without the addition of sugar, fruit juices, and spices to a semisolid mass of homogeneous consistency. It differs from jam in being of higher concentration and finer consistency. It is usually heavily spiced and is frequently prepared without the addition of sugar.

Fruit Paste. Fruit paste or fruit leather, etc., is prepared as described for fruit butter, but is dried in the sun or by artificial heat to a solid consistency or to approximately the consistency of putty.

Fruit Preserves. Preserves are made by cooking the prepared fruit in sugar (sucrose) sirup until the concentration of sugar reaches 55 to 70 per cent. A limited proportion of the sugar used may be in the form of corn sugar or corn sirup. The fruit should retain its form, should be crisp rather than soft, and should be permeated with the sirup without shriveling of the

individual pieces. Government regulations require the use of not less than 45 lb. of fruit for each 55 lb. of sugar.

Candied Fruits. Candied fruits are prepared by gradually concentrating fruits in sirup by repeated boilings until the fruit is heavily impregnated with sugar, this process being followed by drying to overcome stickiness. *Glacé* fruit is prepared by coating candied fruit with a concentrated solution of sugar and confectioners' glucose sirup, followed by careful drying to give a transparent glaze to the surface.

Fruit Confections. This is a general term used to describe candies in which fruits are used. There are on the market a large number of products of this character which vary greatly in appearance, texture, flavor, and in the proportion of fruit used in their manufacture.

STORING FRUIT FOR JAM AND PRESERVES

In America berries, cherries, and other fruits are barreled or packed in 25- to 35-lb. tins or cartons, or in wooden or plastic-lined metal barrels, with or without sugar, and preserved in freezing storage until used for jams or preserves. In Great Britain, and less commonly in Canada and the United States, fruits are packed in barrels and preserved with dilute sulfur dioxide solution, 1,000 to 3,000 p.p.m. of SO_2. The sulfur dioxide is boiled out of the fruit almost completely in making jam later.

JAMS

Jams may be made from practically all varieties of fruits and from some vegetables. In the United States and in the British Empire the small fruits and berries are most popular for the purpose.

Various combinations of different varieties of fruits can often be made to advantage, pineapple being one of the best for blending purposes because of its pronounced flavor and acidity.

Preparation of the Fruit. Fruit for jam making should have reached full maturity in order to possess a rich flavor and be of the most desirable texture.

All berries must be carefully sorted and washed; strawberries must be stemmed; peaches, pears, apples, and other fruits with heavy skins must be peeled; while apricots, plums, and other thin-skinned fruits do not require peeling. Apricots, plums, and fresh prunes can be pitted by machine, such as the Elliott pitter.

Firm fruits should be boiled in a small quantity of water before sugar is added in order to facilitate pulping. In factory practice it is possible to pulp boiled or steamed fruit in a tomato pulper without previous peeling. Stone

fruits, such as plums and apricots, require a very heavy pulping screen because of the abrasive action of the pits. The paddles should operate at moderate speed, so that the pits will not be broken into fine fragments. For jams a coarse screen is used; for butters, a fine one.

Frozen-pack fruits are melted quickly in the jelly kettle. Those preserved in sulfur dioxide solution are boiled with some water until most of the sulfur dioxide is volatilized.

Berries should not be softened by boiling before the addition of sugar. In some plants it is customary to pass the cooked berries that possess prominent seeds through a pulper to give a seedless purée. Apricots and plums are usually pitted by mechanical pitter such as the Elliott machine. They are also sometimes puréed.

Addition of Sugar. Pure fruit jam as defined by the old pure food and drug regulations contains only fruit and cane or beet sugar (sucrose). Glucose in limited amount may also be used under the present regulations.

The proportion of sugar to fruit varies with the variety of the fruit, its ripeness, and the effect desired, although the most common ratio of sugar to fruit is pound for pound. This is usually a suitable ratio for berries, currants, plums, apricots, pineapple, and other tart fruits. Sweet fruits of low acidity, such as ripe peaches, sweet prunes, and Vinifera varieties of grapes, normally require less than an equal weight of sugar, and the ratio may in some cases be as low as ¼ lb. of sugar per pound of fruit.

Boiling. Boiling is desirable in order to cause intimate mixing of the fruit pulp and the sugar and to partially concentrate the product by evaporation of excess moisture.

Berries should be used in small lots and concentrated to the desired consistency as rapidly as possible. Other fruits are more resistant to the action of heat and may be boiled more slowly or in larger lots.

Steam-jacketed copper, stainless-steel, nickel, or aluminum kettles are commonly used in commercial practice for the preparation of jams, small kettles being preferred. Cooking jams in a vacuum pan in order to minimize heat damage is followed in many plants.

End Point. Most jams should be concentrated to a boiling point of 219 to 221°F., the end point varying with the fruit variety, proportion of sugar, and other factors. A jelly thermometer may be used with advantage to determine the end point of the boiling process. An Abbe refractometer is very useful in determining the finishing point. The usual finishing point is 65 to 68 per cent soluble solids as determined by Abbe refractometer.

Use of Pectin. The combining of fruit pulp with pectin is becoming a more general practice in the commercial manufacture of fruit jams, in order to obtain products of jellylike consistency. Its use assures uniformly successful results and permits standardization of operations (page 459).

Vacuum Concentration. Concentration of berry jams in an open kettle results in considerable loss of color and flavor. Experiments and commercial developments have demonstrated that a jam of fresh berry flavor and rich red color and in every respect superior to kettle-cooked jams can be made by concentrating the fruit pulp and sugar in a vacuum pan (see section on vacuum concentration of jellies in Chapter 14).

The capacity of the vacuum pan will be greatly increased if the fruit and sugar are heated to boiling in an open kettle before entering the vacuum pan. If desired, the vacuum pan may be used as an open kettle when the fruit and sugar are first added. This will be necessary for firm fruits that have not been previously subjected to boiling at atmospheric pressure.

Although greater skill is required in the operation of a vacuum pan than a jelly kettle, the output per man can be greatly increased where vacuum concentration is substituted for the open-kettle method of preparing jams, jellies, and preserves, and superior products can be obtained.

Packaging. Some of the jams produced in the British Empire are sold in cans ("tins"). In America the glass container is almost universally used for jams, jellies, and preserves. The processes of filling and sealing are done by automatic machinery, as described for jellies.

Pasteurizing. If the product contains a very high concentration of sugar (70 per cent or above), it will not spoil in most climates. Most commercially prepared jams are not concentrated to this high density, however, and should be pasteurized at 180°F. for 30 min. as described for jellies, or packed at 190 to 200°F. in preheated glass containers, in order to prevent molding or fermentation.

Cooling before Placing in Containers. If allowed to stand at a high temperature too long before packaging and pasteurizing, fruits of delicate color and flavor, such as strawberries, may be injured in quality. Such jams should be cooled as described for jellies.

Use of Glucose Sirup. Low-priced jams for bakers' use, and to some extent for retail sale, are often made with glucose sirup and sugar. The glucose sirup imparts a heavy consistency and is lower in price than sugar.

It is also used within specified ratio to sucrose in jams, preserves, and jellies for the retail trade. Further information on this point is obtainable from the Food and Drug Administration, Washington, D.C.

Formulas with Pectin. If a jam free of seeds is desired, berries are steamed or cooked with a small amount of water until soft and are passed through a tomato pulper to give a seed-free purée. Apricots and plums are steamed until soft; peaches are pitted and peeled before steaming. The hot fruit is coarsely screened to give a coarse purée, free of pits.

The California Fruit Growers Exchange (Sunkist Growers) gives the following formula for use of its citrus pectin with fresh fruit, for a "50-50" jam:

Water	About 2½ gal.
Fruit, prepared as above	100 lb.
Sugar	100 lb.
Citrus pectin, 100 grade	6–8 oz.
Standard citric acid solution (1 lb. acid dissolved in 1 pt. water)	6 fl. oz.

Mix the pectin with eight times its weight of sugar. Heat the water to 160 to 180°F.; add the pectin-sugar mixture, and stir and heat until pectin is dissolved. Add remaining sugar and the fruit. Boil to 68 per cent soluble-solids content (about 221°F. at sea level or 9°F. above boiling point at a specific factory). Add the acid and mix well. Fill at above 190°F. Wash containers and cool in usual manner.

The recommended formula for frozen-pack fruit packed with 3 lb. of sugar per pound of fruit (3-plus-1 pack) is about as follows:

Water	About 2½ gal.
100-grade pectin	4–6 oz.
Sugar	67 lb.
Standard fruit acid solution	6 fl. oz.
Fruit	135 lb.

Proceed as above, cooking to 9°F. above the boiling point of water at a specific factory. Note that less sugar is required than with fresh fruit because of sugar packed with the frozen fruit.

Caution: In both formulas do not add fruit until all the pectin is dissolved. Dissolve the pectin with eight times its weight of sugar in the water at 160 to 180°F. Formulas using apple pectin are obtainable from manufacturers.

FRUIT BUTTERS

The most important fruit butter produced in the United States is apple butter; peaches and plums are used to a limited extent for the same purpose. In continental Europe plums and prunes are used in very large quantities for the preparation of cheap butters and highly concentrated jams, and in Asia Minor the apricot is rather generally used for the purpose.

Preparation of the Fruit. In the commercial manufacture of apple and pear butters, the fruit is cooked until soft with a small amount of water and without previous peeling or coring. Toxic spray residues, if present, must be removed, or the fruit peeled, before cooking and sieving. The softened fruit is then passed through a tomato pulper to remove skins and seeds and generally through a tomato-pulp finisher to impart a smooth texture.

An apple crusher or slicer may be used to crush the fruit before boiling and pulping.

Peaches should be peeled before pulping, and other stone fruits, such as apricots, prunes, and plums, should be pitted, although it is possible to pulp these fruits if very heavy screens are used in the pulping machine. All fruits should be thoroughly cooked before pulping. An excellent pulper consists of a Sprague-Lowe type of tomato-catsup finisher equipped with stiff revolving brushes and a heavy copper screen with about ⅛-in. openings.

One difference between a jam and a butter lies in the screening of the pulp used for the latter. However, as previously mentioned, the cooked berries are often passed through a pulper to remove seeds, and jam is made with the purée.

Preparation of Fruit Butter without Adding Sugar. In the household- and orchard-scale preparation of apple butter, apple juice or apple sirup is often used to replace sugar, but the butter so produced is of a tart flavor. The cider may be added with or without previous concentration, the usual ratio being 1 gal. of fresh juice per gallon of pulp.

The cider and sauce are concentrated by rapid boiling to a thick consistency, and spices are added near the finishing point.

Spices. The usual spices are cinnamon, cloves, and allspice, used in proportion of about $\frac{1}{10}$ per cent each, that is, about $1\frac{1}{2}$ oz. per 100 lb. A small amount of ginger and vanilla extract or nutmeg is also often used.

It has been found that a great deal of the essential oils of the spices will be lost if the spices are added before concentration is nearly completed. On account of its thick consistency, the butter must be stirred thoroughly after the addition of the spices.

End Point. The finishing point is determined by consistency rather than by boiling point, because the boiling point of the finished butter is dependent upon the ratio of pulp to juice and of pulp to sugar. The butter, when cold, should be thick enough to stand when a spoonful is placed on a plate and should not flow. It should, however, be thin enough to spread easily on bread.

Fruit Butters with Sugar. In the preparation of fruit butters from pears and peaches, sugar is generally used instead of fruit juice. Brown sugar is often substituted for refined sugar because a finished product of dark color is usually desired.

The usual proportion is ½ lb. of sugar per pound of pulp. The mixture is then concentrated to a heavy consistency and spiced as described above.

A process employed at the University of California for the manufacture of the pear butter above mentioned is as follows: The ripe fruit is carefully sorted and trimmed. It is crushed in an apple crusher and then boiled with a small amount of water until soft. The softened fruit is passed through a tomato pulper and subsequently through a tomato finisher. To each pound of the pulp is added ½ lb. of sugar. The mixture is concentrated to 218°F.,

and approximately ½ gal. of lemon juice is added per 10 gal. of original pulp. The mixture is then boiled to 221°F., and $\frac{1}{10}$ lb. each of ground cloves, cinnamon, and ginger and $\frac{1}{20}$ lb. of nutmeg, or the equivalent amounts of spice oils or extracts, are added per 10 gal. of original pulp. The boiling is continued for a short time, less than 3 min. The butter is canned or packed in glass and sealed hot, no further sterilization being required.

Plums and other sour fruits can be made into butters by the same formula with the exception that the lemon juice is omitted. Peach butter is improved by the addition of lemon juice as described above for pear butter or by mixing the pulp with that from plums or other sour fruit.

Preservation. Fruit butters require no sterilization if packed boiling hot and sealed at once, or if concentrated to a boiling point of 221°F. or higher, but under other conditions they require pasteurization as described for jellies.

Butters that have been highly concentrated may be preserved satisfactorily by placing them in scalded jelly glasses, stoneware jars, etc., and sealing with paraffin.

CANNED SAUCES

Apples are peeled, cored, quartered, steamed, pulped, and cooked, with 1 part of sugar to about 6 of fruit. The sauce is usually sieved before canning. It is canned hot, sealed, and processed a short time at 212°F. If it is canned and sealed at 185°F. or above, further processing is unnecessary (see Chapter 8 for details).

Other fruit sauces may be prepared in similar fashion.

PRESERVES

Fruit preserves of good quality should retain the form of the original fruit and should consist of the whole or cut fruit in a clear sirup of high sugar concentration. The fruit should not be caramelized by overcooking and should retain most of the color of the fresh fruit.

Preparation of the Fruit. Fruit is prepared for preserving as for canning. Some fruits, as peaches and pears, are also sliced.

Open-kettle One-period Process. The usual process for the preparation of fruit preserves consists in boiling the fruit in steam-jacketed kettles with sugar or in sirup until a sirup of heavy density is obtained and the fruit is thoroughly impregnated with the sirup.

Firm fruits, such as peaches, pears, and figs, require a long period of boiling in order to impregnate them with the sirup, while berries should be boiled only a very short time or cooked under vacuum in order that the fruit shall not be badly softened.

The end point of the boiling process is most conveniently determined by means of a thermometer or by an Abbe refractometer, as in the preparation of jelly. The sirup should have a final concentration for most fruits of 65 to 68° Balling, or the boiling point should be approximately 219 to 221°F. at sea level.

The objection to the open-kettle one-period process is that it may result in serious injury to the flavor and color of the finished product. Its advantage lies in its rapidity and low cost of operation.

The Slow Open-kettle Process. In order to avoid undue injury to the color and flavor of the fruit, the slow process of preserving may be employed. In this the fruit is heated for a short time on successive days in sirups of progressively increasing sugar concentration.

It is customary to place the fruit first in a solution of 39 to 40 per cent sugar and to boil long enough to render the fruit tender but not soft. The mixture is then set aside for 24 hr. More sugar is added to increase sugar concentration about 10 per cent above that of the first sirup. The mixture is then boiled a short time, usually 3 or 4 min., and is set aside again for 24 hr. The process is repeated until the product is of the desired consistency. It is then placed in the final containers and sterilized.

Vacuum Cooking of Preserves. The advantages enumerated for the vacuum cooking of jams apply equally well to the vacuum cooking of preserves.

Fruit that is to be cooked in vacuum should first be cooked sufficiently at atmospheric pressure to render it tender.

For firm fruits, concentration must be slow in order to permit penetration of the fruit by the sirup. Soft fruits may be concentrated rapidly.

The finishing point is determined by the Balling test or by refractometer readings of samples of the sirup withdrawn while boiling is in progress. There is danger of concentrating the sirup to such a point that crystallization of the cane sugar occurs, and the final concentration should not exceed 68° Balling.

Vacuum-cooked preserves are superior in flavor and color to preserves made in an open kettle.

Cooling of Preserves. In order to retain the fresh flavor and color of the fruit most satisfactorily, the jars or cans of preserved fruit should be cooled as soon as possible after the cooking process is completed.

Sterilizing. If filled into the jars or cans at 190 to 205°F., preserves need not be sterilized in the container, but in commercial practice it is often desirable to pasteurize as described for jellies.

Preserving Methods for Various Fruits. The processes of preparing preserves from various fruits differ considerably in important details, and it is therefore deemed advisable to give brief descriptions of the more

common methods followed in preserving some of the more important fruits.

Strawberries. Use firm-ripe berries of good color. Sort carefully and stem. Wash. Place in a preserving kettle with an equal weight of sugar. Heat slowly to the boiling point with gentle stirring. Avoid crushing of the fruit. Boil 3 to 4 min. Chill to room temperature as quickly as possible on a cooling table or by circulating cold water in the jacket of the kettle. Allow to stand, with occasional gentle stirring, until the berries have thoroughly absorbed the sirup and have ceased to float. This may require several hours.

Pack into glass jars, and seal jars in a vacuum sealer. Pasteurize in water at 180°F. for 30 min. Cool to room temperature as rapidly as the glass will permit.

The use of added pectin and acid in the making of strawberry and other fruit preserves is illustrated by the directions for their application given by the California Fruit Growers Exchange (Sunkist Growers) research department (1945). They are about as follows:

For Fancy-quality strawberry, raspberry, plum (except Damsons), canned pineapple, blackberry, and grape (presumably Concord), use the following quantities of materials: water 2½ gal., or 25 lb., fruit 100 lb., 100-grade citrus quick- (rapid-) set pectin 6 to 8 oz., sugar 100 lb., and standard fruit acid (1 lb. acid per pint of water) 12 fl. oz.

Place the water in a jelly kettle and turn on the steam. Thoroughly mix the pectin with eight times its weight of sugar in a dry pan. Heat the water to 160 to 180°F. and stir in the sugar and acid mixture and with stirring bring to a boil and boil for about ½ min. Add the fresh fruit (or the canned fruit, if pineapple) and the remainder of the sugar. Boil rapidly to the finishing temperature such as 68 to 70 per cent soluble solids or to 223°F. Allow to stand a short time for bubbles to escape. Pack into glass jars or other containers at 190°F. or above and seal. Cool as previously directed for jellies in Chapter 14. It will be noted that the mix is cooked slightly beyond 68 per cent soluble solids, because at the end of the cooking period the fruit and the sirup have not yet come to final equilibrium in respect to sugar content. After packaging, the exchange of sugar between the two will continue and level off at about 68 per cent soluble solids.

For 3-plus-1 frozen-pack fruit the formula must be modified to take account of the sugar added at the time of freezing. The formula then becomes about as follows: water about 20 lb., fruit 133 lb., sugar 67 lb., quick-set 100-grade citrus pectin 6 to 8 oz., and standard fruit acid solution (see preceding formula) 12 fl. oz. Dissolve the pectin with eight times its weight of sugar in the heated water as in the proceding formula. Under *no circumstances* should the fruit be added until the pectin is thoroughly dissolved. Then add remaining sugar and cook to 221°F. Pack at or above 190°F., seal and cool in the usual manner. With 2-plus-1

frozen-pack berries the procedure is the same, except that 150 lb. of fruit and only 50 lb. of sugar are used. Formulas with apple pectin are available from manufacturers.

In one large California establishment the procedure with fresh strawberries is about as follows: The fresh berries arrive in stemmed condition, having been stemmed by the picking crew. They are spray-washed and then carefully sorted from a slowly moving belt to remove all moldy, green, overripe, and otherwise unfit berries. A weighed quantity of berries is put in each of a rather large number of 5-gal., widemouthed enamel-lined cans with a weighed amount of sucrose sirup (liquid sugar) of about 67° Brix; and 4 to 5 lb. of dry dextrose sugar is added to cover the berries and sirup in order to minimize oxidation. The cans of berries are allowed to stand overnight. The mixture is then placed in a steam-jacketed kettle, with additional sugar if needed, and heated to about 180°F. It is then transferred by suction to a vacuum pan (the plant has three of these) and is concentrated at 150°F. at 20 to 25 in. vacuum to desired soluble solids, determined by refractometer, requiring about 20 min. Liquid pectin and acid are then added. The preserves are transferred to a filling pan, heated to 195°F., and then filled into glass containers by automatic filling machine; the glasses are sealed with White Vapor Vacuum caps, allowed to travel by conveyer a short distance, washed in hot-water sprays, and cooled with water sprays. Acid is not always added but may be added if desired to give a stiffer gel and more tart taste.

Mackinney, Lukton, and Chichester (1955) have conducted extensive research on the changes that occur during the cooking and subsequent storage of strawberry preserves. They have concluded that oxidation of the anthocyanin pigment during cooking and after packaging is a major cause of loss of anthocyanin. Ascorbic acid and levulose sugar hasten the breakdown of the pigment. On continued storage of the preserves, oxidative loss of color with browning of the preserve's color occurs. The authors point out that browning caused by the Maillard reaction between hexose sugars and amino acids requires an induction period of several weeks at 70°F.; also that in commercial preparation of strawberry preserves by cooking in an open kettle, from 30 to 70 per cent of the anthocyanin pigment is lost. They conducted a considerable number of experiments in the cooking of the frozen 4-plus-1 strawberries under high vacuum at 90 to 100°F. Color retention was very greatly improved in comparison with that found by boiling in the open above 212°F. It is possible to retain 90 per cent of the pigment by this vacuum-cooking procedure. Concentration to 75 per cent soluble solids is advised; it will then equilibrate at 68 per cent after packing and storage. Pasteurization after packing appears advisable, as is also sealing of the glasses under vacuum in order to reduce O_2 content of the product. They report that fresh strawberries examined by

them had 35 to 55 mg. of anthocyanin per 100 grams, but that commercially made samples of preserves contained only 3 to 13 mg. of the pigment per 100 grams; in fact, only one sample contained as much as 13 mg. per 100 grams. However, the deterioration of the pigment and development of a brown color after the preserves are warehoused or placed on the grocer's shelf is still a serious problem, even if vacuum cooking is used.

A number of years ago a California preserver got around this problem to some extent by adding to the berry and sugar mix before cooking a certain amount of deeply colored, red-grape juice. Its addition is still good practice, perhaps, but such addition would probably have to be declared on the label. The heat-extracted juice of such a variety of grape as the Petite Sirah, Barbera, or Alicante should prove satisfactory for this purpose. Recent experiments by the author indicate that this method of color improvement of strawberry preserves is worthy of consideration. Vinifera varieties of grapes, rather than Labrusca, are advisable since the Concord and other Labrusca varieties are of too pronounced a flavor.

Other Berries. Other berries may be preserved in the same manner as described for strawberries, although they are not so liable to soften and disintegrate as are the latter and will usually withstand more vigorous and longer boiling than strawberries.

Fig Preserves. A number of methods are in commercial use for preserving figs. In Texas the Magnolia variety of fig is used. The fruit, according to Reed, is lye-peeled in boiling dilute lye (usually about 1 per cent sodium hydroxide) and is rinsed under sprays of water. It is placed in a dilute sirup of approximately 30° Balling, slowly concentrated by boiling in open kettles to 60 to 65° Balling, packed hot in jars or cans, and sealed at once. Sterilizing in the container is usually omitted.

In California the slow process is sometimes used. The figs, usually of the Kadota variety, are blanched in water near the boiling point until tender. They are then boiled a short time in dilute sirup or are heated to 185°F. and then set aside for about 12 hr. On succeeding days the sirup concentration is progressively increased and the heatings are repeated until the desired consistency is obtained.

In another process the blanched fruit is placed in sirup at 180 to 190°F., and this temperature is maintained for about 2 hr., during which period the sugar concentration is increased by the addition of sugar that is dissolved by stirring. The fruit is then set aside in the sirup overnight and packed. The finished product is of very attractive appearance and flavor.

Single-period boiling of the fruit in open kettles, more commonly used in California, results in considerable breaking of the fruit and rather heavy loss during sorting and packing. Approximately equal parts by weight of blanched figs, water, and sugar are cooked to 218 to 221°F. The boiled fruit should be allowed to stand overnight to absorb the sirup before

packing. The broken fruit must be used for jam, which is sold at a lower price than the preserves.

During the harvesting season some figs are canned in water and later used for preserving.

Peaches and Pears. These fruits are peeled and cored or pitted as for canning and, in addition, usually sliced. California clingstone varieties of peaches are often diced for preserves. Peaches may be lye-peeled whole, cut lengthwise but not pitted, or pitted and sliced, and cooked to a preserve as follows:

The prepared fruit is placed in a sirup of approximately 30 per cent sugar and is boiled slowly to the desired concentration. This will be for peaches about 55 to 60° Balling and for pears about 60° Balling (corrected for temperature). If placed in too concentrated a solution, the fruit will shrivel and become tough. The use of a dilute sirup for the preliminary stages of the process softens the fruit and permits penetration of the fruit by the sirup.

A modification of the above process consists in boiling the fruit in water until tender, followed by the addition of sugar and a amall amount of water to give a heavy sirup in which the fruit is cooked a short time.

Cherries. Sour cherries are pitted mechanically and cooked to a preserve consistency with water and sugar equal in weight to the fresh fruit. Sweet cherries, such as the Royal Anne and Black Tartarian, are seldom used in this manner. Royal Anne cherries are more often used for preparation of Maraschino cherries (see next section).

Maraschino Cherries. With the advent of canned fruit salad and canned fruit cocktail, large quantities of cherries, usually Royal Anne and other white varieties, came into use for barreling and subsequent preparation of Maraschino cherries. Considerable quantities of barreled cherries also are used in preparing Maraschino cherries in sirup for use in mixed drinks, ice cream, etc. Barreled cherries are used also in preparing candied and *glacé* cherries for confectioners' and bakers' use.

Barreling is a simple procedure; although if improperly done, e.g., if too little preservative (sulfur dioxide) is used, it may result in complete loss of the fruit by fermentation. If too much sulfur dioxide is used, the fruit may be lost by softening.

The orchard run of fruit, usually Royal Anne or other white variety, is gathered before it is fully mature. Royal Annes should have attained full size but should not have developed much pink color or indeed any color at all; i.e., they should be white in color or colored with only a faint blush of pink. The stems are usually not removed at this time. Red varieties of cherries may be used if picked slightly immature.

The fruit is packed in paraffin-lined spruce barrels after removing one head from the barrel. The head is replaced, the hoops are driven in place, and the barrel is filled with the preservative brine.

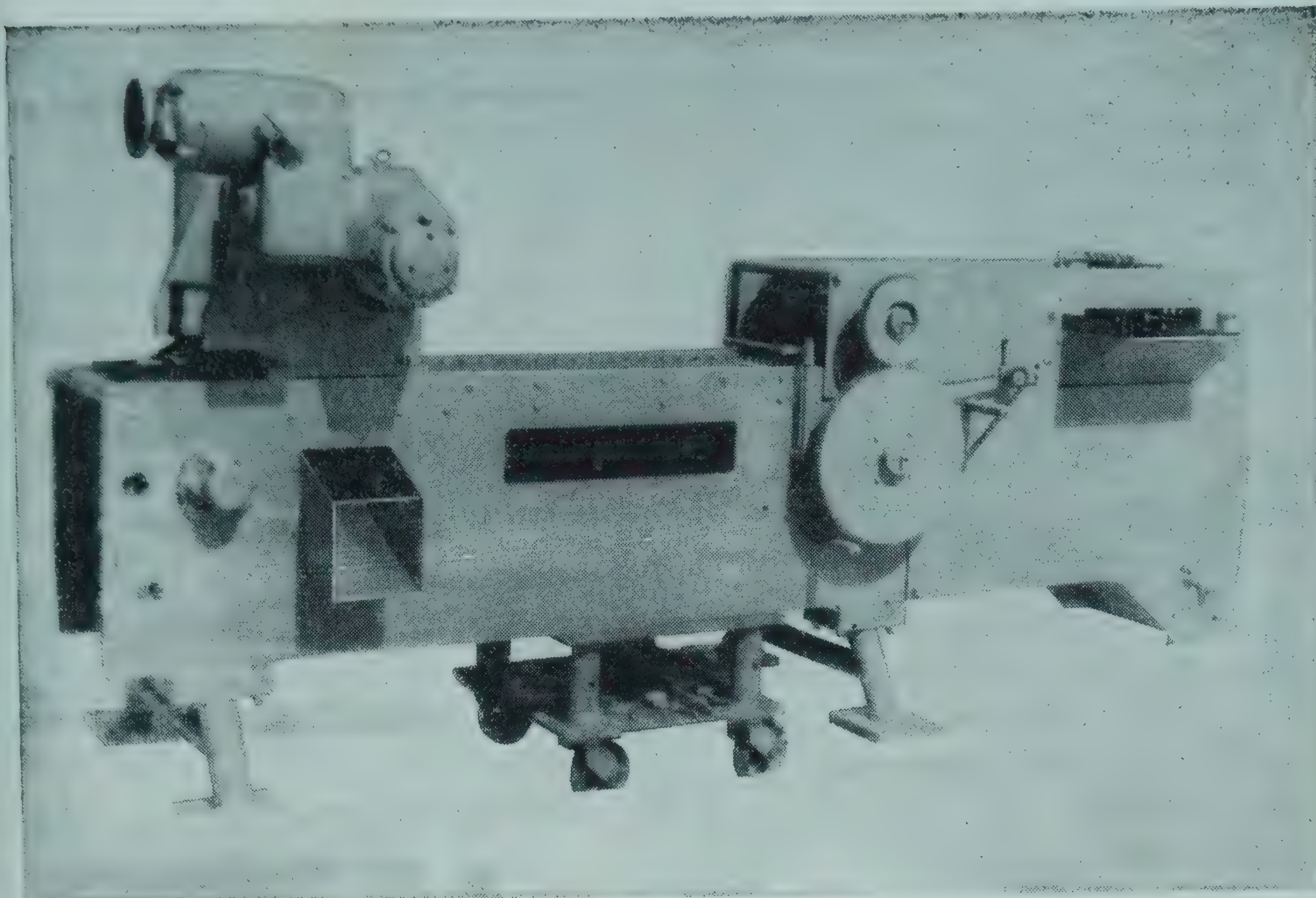


FIG. 72. Pitter for cherries for Maraschino processing. A similar machine is used for olives. (*Geo. W. Ashlock Co., Oakland, Calif.*)

In most cherry-brining establishments large wooden tanks are used instead of 50-gal. barrels. A large plant in Oregon has over 500 tanks of 13,000 gal. capacity. Most of these are in the open and covered with sheet aluminum to exclude rain and minimize loss of SO_2. The usual brine employed in California is made up of about 0.75 to 1.0 per cent of sulfur dioxide and about 0.4 to 0.6 per cent of unslaked lime; i.e., a little more than half as much lime is used as sulfur dioxide. If too little lime is used, the resulting low pH value will cause splitting of the cherries and cracking of the skin. If too much lime is used, the sulfur dioxide will have no preservative effect and spoilage by yeast will ensue. In Oregon approximately 1.5 per cent sulfur dioxide and about 0.90 per cent of lime are used.

In preparing the brine the water is measured into a tall wooden tank. The lime is weighed and is made into a thick milk of lime with a few gallons of water. This milk of lime is then added to the tank of water and maintained in suspension by a mechanically operated wooden stirrer. At the same time a cylinder of liquefied sulfur dioxide is placed on a portable scale and connected to a tube that enters the bottom of the tank. Iron should be avoided. The desired amount of sulfur dioxide by weight is bubbled into the lime suspension in the tank with constant stirring. The lime goes into solution because of formation of calcium bisulfite, $Ca(HSO_3)_2$, and when the reaction is complete, a nearly clear solution results.

The sulfur dioxide content of this solution should be checked by titration

with standard $N/10$ iodine solution, using starch solution as an indicator. A 10-cc. sample plus 50 cc. of water plus about 5 cc. of 1:3 sulfuric acid is satisfactory for titration. One cubic centimeter of $N/10$ iodine equals 0.0032 gram of sulfur dioxide. The titration is made directly without need of distillation.

The brine is added to the barreled cherries, and the barrels are bunged tightly. It is often desirable to add more brine after 24 hr. to fill the space formed because of absorption of the brine by the fruit and wood of the barrel. The barrels should be rolled once a day for several days to ensure dissolving of all the lime; if undissolved lime is present, it may settle to the bottom of the barrel, where it may cause the liquid to be alkaline or neutral, with subsequent damage to the fruit. When tanks are used the lime and SO_2 are mixed with the water by pumping over. Tank cars lined with Amercoat, tank trucks, and 50-gal. barrels are used for shipment of the brined cherries. At one plant it was said that the SO_2 content of the brine decreased in storage to about 0.4 per cent.

After about 4 weeks' storage the cherries are usually ready for use, although the barreler observes the degree of curing by noting the color and texture of the fruit. The sulfur dioxide bleaches it to a translucent white or cream-yellow color. The calcium hardens the tissues, probably by combining with pectic substances. Some barrelers also add alum to the brine, but this may so increase the hydrogen-ion concentration that cracking and softening result.

If they are to be used in canned fruit salad or canned fruit cocktail, the cherries at the cannery are stemmed mechanically and pitted by an Ashlock or other similar power-operated pitter. The pitted fruit is soaked 24 to 48 hr. in barrels in running water to remove most of the sulfur dioxide. It is then boiled in several changes of water in steam-jacketed kettles until tender and until the sulfur dioxide content is reduced to below 20 p.p.m. Some factories omit the soaking in cold water. If too much sulfur dioxide is left in the cherries, the canned product will attack the tin plate, causing hydrogen swelling, or if very much sulfur dioxide is present, formation of hydrogen sulfide and black ferrous sulfide will occur.

Leaching with water reduces both the SO_2 content and the acidity, a change that favors penetration of the fruit by the dye.

The cherries are then boiled a few minutes in dilute erythrosin dye solution (usually 0.02 to 0.05 per cent). This dye is precipitated by the acid of the fruit and therefore penetrates only a short distance into the flesh unless the pH has been increased to 4.5 or higher. The fruit is allowed to stand in the dye in open barrels for 24 hr., when it may be boiled a second time. About 0.25 per cent of citric acid may be added to the water used for this boiling. It is then rinsed in water and added to the other fruits used in canned fruits for salad or in canned fruit cocktail. For the latter

product the cherries are sliced or quartered. This method of dyeing the fruit greatly reduces its tendency to "bleed" and stain the other fruits with which it is canned in salad and cocktail. Some authors recommend dyeing the cherries in a dilute sodium bicarbonate solution of erythrosin, as the bicarbonate renders the fruit alkaline and hence the dye penetrates deeply and quickly. The fruit is then acidified by storage for 24 hr. in dilute (0.5 per cent) citric acid solution. This procedure gives an evenly colored cherry, but the dye may bleed badly after canning and stain the surrounding fruit. Therefore the author prefers the first method described above.

In preparing cherries for use in cocktails, a somewhat different procedure is employed. The cherries are pitted, "soaked out" with cold water, and boiled in several changes of water until tender and practically free of sulfur dioxide. In the University of California laboratory the following cooking procedure has proved satisfactory: To a cane- or beet-sugar sirup of 30° Balling are added 0.20 per cent sodium benzoate, 0.5 per cent citric acid, and 0.02 per cent ponceau 3R dye. The fruit, previously pitted and freed of sulfur dioxide as described above, is then added, and the mixture is boiled 2 to 3 min. The sirup and fruit are set aside in dishpans for 24 hr. to absorb the sirup. The sirup is removed, and sugar is then added to it to increase the Balling to 40°; artificial cherry flavor is added to suit; the fruit and sirup are again brought to boiling, packed hot, and sealed in glass jars. The flavoring may be purchased from any reputable bakers' and confectioners' supply company, or may be prepared by dissolving about 5 per cent of pure bitter-almond oil in pure ethyl alcohol (free of wood alcohol) and adding small amounts of neroli oil and pure vanilla extract made from vanilla beans. This is a very powerful flavoring agent. Avoid overflavoring of the sirup.

The sodium benzoate is for the purpose of preserving the cherries for use in bars and cafés after the jar has been opened. Its presence must be declared on the label. If the cherries are packed at or above 190°F. in small jars for home use, the benzoate is omitted.

For candying, Atkinson recommends dyeing the cherries with dilute erythrosin in preference to ponceau 3R. Some preservers prefer a mixture of ponceau 3R and amaranth, about 0.01 per cent of each. These two dyes are soluble in the presence of acid, whereas erythrosin is precipitated at even very slight acidity. Ponceau 3R is brick red in color, amaranth is purplish red, and erythrosin is deep pink.

See the last part of this chapter for candying cherries and other fruits.

Spiced Preserves (Sweet Pickles). Spiced preserves are prepared principally on a household scale, but it is believed that their manufacture on a commercial scale should provide a considerable outlet for fruits suitable for preserving purposes.

Peaches, pears (particularly small varieties such as the Seckel), figs,

quinces, and other firm fruits are those most commonly used for sweet pickles.

The fruit is prepared as described elsewhere for sweet preserves, boiled in water until tender, and then placed in a spiced sirup. The formula given below is typical of the sirups used for the purpose:

Sugar	14.0 lb.
Vinegar (cider vinegar of 4 per cent acetic acid)	3.0 pt.
Water	7.0 pt.
Ginger root, broken	½ oz.
Whole cloves	½ oz.
Stick cinnamon	½ oz.

The fruit is heated to boiling in this sirup and allowed to stand overnight. The sirup is then increased to 60° Balling by the addition of sugar. The fruit and sirup are heated for 3 or 4 min. and are packed boiling hot into jars or cans. Normally no further processing is necessary, although if the sirup and fruit cool to below 180°F. before packing in the final containers, the product should be pasteurized at 180°F. for 30 min. or processed at 212°F. for 10 min. to ensure against spoilage. If the spices are tied in a cheesecloth bag, they may be removed from the sirup after preserving is completed. Spice oils and extracts are much more convenient than the dry spices (see Chapter 8 for spiced fruits).

CANDIED FRUITS

The manufacture of candied and *glacé* fruits has in the past been a highly specialized industry in which success has depended to a very great extent upon the skill and experience of the individual workmen. A very large proportion of the work has been done by hand labor and with small individual lots of fruit. Undoubtedly, the processes for the candying of fruits lend themselves to factory methods, and existing factory equipment could be employed to greatly reduce the cost of manufacture and the price to the consumer. In fact, in California plants the fruit is treated in bulk in metal tanks.

General Principles. The candying process consists essentially of slowly impregnating the fruit with sirup until the sugar concentration in the fruit is high enough to prevent spoiling. The process must be so conducted that the fruit does not soften and become jam or become tough and shriveled. Repeated boiling and storage in sirups of progressively increasing sugar concentration will accomplish the desired results.

Following impregnation, the fruit is washed and dried. It may be packed and sold in this form, or it may be coated with a thin glaze of sugar and

glucose sirup—*glacéd.* This is done by dipping the dried candied fruit in a sirup and again drying the surface.

Preparing Fruit. Frequently the fresh fruit is stored in a dilute solution of sulfurous acid, or sulfur dioxide and lime solution, in order to bleach the color, harden the tissues, and to preserve it until needed, as described for Maraschino cherries.

Whole Fruits. Fruit preserved in sulfurous acid must be thoroughly leached repeatedly in hot water to remove all taste of sulfur dioxide before the candying process is begun. Cherries are stemmed and carefully pitted before leaching. Apricots should be pitted without cutting the fruit in half. Small pears, plums, prunes, and other whole fruits are often pricked with copper wires.

Fresh fruits and canned fruits can be used for candying purposes without the intermediate step of storage in sulfurous acid. Figs, peaches, pears, and pineapple are particularly well suited for use fresh.

The jujube, or Chinese date, now produced in commercial quantities in the United States, is excellent for the preparation of candied fruit. The skin of the fruit must be punctured very thoroughly by means of metal needles, or slit.

Berries are very difficult to candy because of their tendency to soften.

Other fruits should be boiled in water until tender, after preparation as described above.

Use of Canned Fruits. All firm varieties of canned fruits may be used very satisfactorily. Pineapple, peaches, figs, and pears are particularly desirable for the purpose.

Firm Fruit Necessary. Frequently fruit which is at the best stage of maturity for table use is too soft for the preparation of candied fruits. Firm-ripe or even slightly immature fruit is better than thoroughly ripe fruit.

Sirup Treatment by Slow Process. As formerly practiced, the impregnation of the fruit with sugar was a process that required a long period of time and frequent manipulation of the fruit in small containers.

Commercial practice varies greatly in regard to the application of the sirup; hence the process described below is general in nature, although it has given good results in experiments made upon a semicommercial scale.

A sirup of approximately 30° Balling is first prepared by use of 1 part by weight of glucose sirup or of invert sirup, 1 part by weight of sucrose sugar, and enough water to give the desired Balling degree. The above concentration of 30° Balling will be obtained by dissolving approximately 1 lb. of the mixed glucose and sugar in 2 pt. of water.

Unless glucose or invert sirup is used, the candied fruit will dry too completely and become hard and granular. The glucose corn sirup prevents

overdrying and also improves the appearance of the finished product by causing it to be more translucent than would otherwise be the case. Invert sirup is better for the purpose because candied fruit made with it is not so apt to become tough and hard.

The fruit, prepared by previous treatment in sulfurous acid and boiling to render it tender, or by boiling of the prepared fresh fruit, is placed in the sirup. Canned fruits are placed in this sirup direct from the can. The fruit and sugar are boiled for a short time, 1 or 2 min., and the mixture is then set aside for 24 to 48 hr. to permit equalization of the sugar in the fruit and sirup. Large dishpans are ordinarily employed for storage. Small steam-jacketed tilting jelly kettles are used for boiling the fruit and sirup. In many plants the fruit and sirup are heated in stainless-steel tanks by closed steam coils. A temperature high enough to cause satisfactory penetration of the sirup is maintained (see next section).

If the fruit tends to float, it may be submerged in the sirup by means of a floating wooden rack or wire screen.

After 24-hr. or longer storage, in the "dishpan" method the sirup is drained from the fruit and is made up to approximately 40° Balling by the addition of cane sugar and glucose, by weight approximately 1 part of glucose to 1 part of cane sugar. For the Maraschino type of candied cherries, the sirup should be colored by the addition of a small amount of permissible red coal-tar dye, such as erythrosin or ponceau 3R.

The fruit is brought to the boiling point in the sirup and is again set aside for 24 to 48 hr. The shorter time is preferable in order to avoid fermentation and molding. The sirup is then increased to 50° Balling in the manner described above, and the fruit is brought to boiling and set aside for another 24-hr. interval. The process is repeated on succeeding days, with an increase of 10° Balling each day until the sirup has reached approximately 72° Balling. Better results are obtained by increasing the sirup concentration 5° Balling, rather than 10° Balling, each day.

This concentration is maintained until the fruit and sirup have thoroughly equalized in sugar concentration. The fruit should remain in this heavy sirup at least 3 weeks in order to become plump and impregnated with the sirup.

Quick Process. Atkinson and others have found that sirup impregnation of the fruit can be shortened to a few hours by maintaining the fruit and sirup at about 140 to 150°F. in stainless-steel or glass-lined tanks.

In experiments conducted by Jang and Cruess at the University of California (1949) four quick methods of candying several fruits were studied, in comparison with the slow, or dishpan, method formerly in general commercial use.

In quick-method A, the fresh fruit was cooked until tender in 30° Brix sirup made up of sucrose and corn sirup in equal portions added to water

and dissolved to give 30° Brix. It was then placed in shallow, stainless-steel pans in an air-blast dehydrater at 150°F. and the fruit generously covered with sucrose–corn-sirup, sirup of 40° Brix. During dehydration in the air-blast dehydrater 40° Brix sirup was added periodically to keep the fruit well covered. Evaporation of water from the sirup caused its concentration to about 68° Brix in 24 hr. The fruit and sirup were allowed to stand several days to allow equilibrium in solids content to become established. The fruit was then drained, rinsed in hot water, drained and dehydrated to desired moisture content, about 20 per cent. It is advisable to have a screen in the pans to keep the fruit immersed in the sirup. This is essentially the W. K. Nichols process formerly used commercially.

In quick-method B, the fruit and sirup were maintained at 150°F. in a stainless-steel vessel by heat applied externally. At intervals of 3 to 4 hr. sucrose and corn sirup were added to increase the Brix degree 10° Brix above that at the beginning of the 3- to 4-hr. period. This was continued until the Brix degree was about 68. The fruit was allowed to stand at room temperature in the sirup for 24 hr.; it was then drained, rinsed in hot water, and dried to desired moisture content in an air-blast dehydrater. This method has been used commercially in the United States and abroad and is similar to the Atkinson (Canada) method.

In quick-method C, the fruit previously cooked until tender in boiling 30° Brix sucrose–corn-sirup sirup was cooked *in vacuo* at 28 in. vacuum in a laboratory vacuum pan equipped with condenser for the distillate. During cooking, sirup of 30° Brix was added periodically to maintain a fairly constant volume in the pan. When the sirup attained 68° Brix the fruit and sirup were removed and allowed to stand for about 24 hr. at room temperature. The fruit was then drained, rinsed in hot water, and dried as described above. This is more or less the procedure that has been followed by some processors in the commercial vacuum cooking of fruits for candying.

In method D in our experiments, a procedure that we believe is novel and has not been used commercially, was followed. The fruit was first cooked until tender in 30° Brix sucrose–corn-sirup sirup. It was then drained and placed in a heavy-walled vessel that could be evacuated and sealed airtight. Heavy sirup of 75 to 80° Brix was introduced into the vessel to completely cover the fruit. The vessel was sealed, and a high-vacuum source was connected to it and a vacuum of over 28 in. was attained; the apparatus was then sealed and allowed to stand 24 hr. No heat was applied during this period. Then the apparatus was opened, and the sirup again brought to 75 to 80° Brix by addition of corn sirup and sucrose and left at 28 in. vacuum for 24 hr. The fruit was then removed, drained, rinsed with hot water, drained, and dried, as above. This method proved not only to be rapid, it also gave candied fruits that were plump and translucent. The process is naturally more effective if the fruit and sirup are maintained at a

warm temperature, say, 100 to 110°F. Flavor and color retention are good. The method was used successfully with fresh apricots, canned Kadota figs, canned halved or quartered cling peaches, and canned Bartlett pears. The weights of the fruits before and after candying by method D and method A (the slow process) were compared. There was little difference.

Draining and Drying. After the sirup treatment is complete, the fruit should be thoroughly saturated with the heavy sirup and should be plump and firm. It should be tender in texture and not tough or shriveled. The sirup should be free from sugar crystals and of about 72° Balling at the time the fruit is ready for drying.

The fruit is removed from the sirup, and the surface is washed with a wet cloth or sponge or the fruit is dipped momentarily in boiling water. It is then placed on screens to dry. Drying may be accomplished at room temperature but takes place more rapidly and with more uniform results if done by artificial heat at a temperature of 120 to 140°F. At too high a temperature the sirup may dry in the form of flakes and separate from the fruit.

The drying should be continued until the fruit is no longer too sticky to be handled. If finger marks are to be avoided, the fruit should be handled with tongs or special forks.

Glacéing. Candied fruit is usually coated with a thin, transparent layer of heavy sirup that dries to a more or less firm texture.

A sirup that has been produced at the University of California is made of about 3 parts of cane sugar, 1 of corn sirup, and 2 of water, cooked to a boiling point of about 236 to 238°F. (24 to 26°F. above the boiling point of water). This is cooled to about 200°F., and the drained, dried candied fruit is dipped in it by means of a fork or wire dipping "spoon." It is drained on screens and is then dried a short time at 120°F. On cooling, the coating should be reasonably free of stickiness.

The author has found that drained candied fruit may be coated fairly satisfactorily by dipping it in a 1½ per cent pectin solution and drying at 120°F. for about 2 hr. The coating is not glossy but nevertheless is fairly attractive. It is not sticky. This process is covered by public-service patent and may be used without payment of royalty.

Brining and Candying of Citrus Peels. Large quantities of candied citron and candied orange peel are used in bakery products and confectionery. A considerable commerce exists in the brining of citron peel in Corsica, Italy, Greece, France, and Palestine, with export to the United States, Great Britain, and other countries. The brined peel is converted into candied citron in factories in importing countries.

The Italian method of brining is described by American Consul A. S. Cheney of Messina as follows: The citron, which is a citrus tree fruit *and not citron melon*, is brought to the seashore, where each fruit is split in half

longitudinally. The halved fruit is placed in large casks ("pipes"). These are headed up, placed on their sides, and filled with sea water. The bung is left open. Fermentation ensues and is complete in about 8 to 10 days. The casks are then opened, the spoiled pieces of fruit are removed, and the casks are again filled with the sound fermented fruit. Each cask holds about 840 lb. of fruit. About 35 to 40 lb. of coarse salt is added, the heads are replaced, and the hoops are driven in place. They are filled with sea water, bunged, and rolled to dissolve the salt. They are then ready for export.

McCulloch states that owing to the cooler temperature, fermentation of the peel in brine lasts about 40 days in Corsica. She states that a certain yeast and a bacterium seem to be essential to proper curing of the peel.

In experiments with Californian citron peel, D. Glickson and the author found that storage in fresh sea water reinforced with 15 per cent of salt gave better results than the Corsican and Sicilian method, as excessive softening occurred in these latter brines. Storage in 15 per cent pure salt brine (60° salometer) containing 2,000 p.p.m. of sulfur dioxide gave a product of light color and of excellent candying quality, although not of so rich a flavor as that stored in brine containing no sulfur dioxide. Softening occurred in brines of initial salt content of less than 15 per cent salt (60° salometer). During storage such a brine decreases to about 8 per cent salt. On that account more salt must be added after fermentation is completed to bring the brine to about 60° salometer. It was found necessary to seal storage containers after fermentation ceased, in order to prevent mold growth. Yeasts were the principal organisms found during fermentation. The addition of 1 per cent of calcium chloride to plain salt brine gave a very firm peel.

Candying consists in removing the central juice tissue and boiling the fruit in several changes of water to remove salt and to make the peel tender, followed by treatment with sirup. This latter consists in candying by the slow process in sirups of progressively increasing sugar content, as described previously for other fruits. Equal weights of invert sirup and cane sugar, or of glucose sirup and cane sugar, are used in preparing the sirups. The initial sirup is about 30° Balling, and the final is 75° Balling. The process requires about 10 days to attain 75° Balling. The fruit is stored in this final sirup for several weeks, drained, wiped free of sirup with a wet cloth, and dipped in saturated hot sugar sirup. On drying, the fruit then acquires a sugar coating. One of the quick processes previously described may be used.

Orange, grapefruit, and lemon peels may be handled in similar fashion except that fermentation should be avoided. A brine of 15 per cent salt (60° salometer) and 2,000 p.p.m. of sulfur dioxide is recommended. Candying is as described for citron. The juicy pulp is removed from orange and lemon peel, but not from citron, before brining.

USE OF FRUIT FOR CHOCOLATE-COATED CANDIES

Fruits lend themselves well to coating with chocolate and are used in a variety of forms for this purpose.

Chocolate-coated Frozen Fruit. Fresh fruit has been used successfully for chocolate dipping, although only very sweet fruit meets with favor from the consuming public. The fruit may be used whole or in the form of ground pulp. In either case it is frozen and is then dipped in melted confectioner's chocolate.

The chocolate congeals at once, and the dipped product must be held in a refrigerator until served.

It is possible to mix gelatin, agar-agar, pectin, or other jellying material with the pulp and sugar and so obtain a product that will solidify at room temperature and can be coated.

Chocolate-coated Candied Fruits. Fruit may be candied as previously described and may then be successfully dipped in chocolate. The chocolate should be melted at not above 100°F. and should be used at about 85°F. in order to prevent streaking and whitening of the coating.

Fruit Jelly Candies. Candies of jellylike consistency can be readily prepared by mixing fruit pectin with fruit pulp and sugar in the proper proportions. In commercial-size experiments at the University of California, various fruits were converted into pulp by boiling and pulping in a tomato pulper to remove seeds and skins. To the pulp was added enough commercial pectin, as determined by trial, to give, on concentration to 222 to 223°F. with invert sirup or glucose sirup and sugar equal to the weight of fruit, a product that solidified to stiff jelly on cooling. The jelly was allowed to harden in a layer about ½ in. thick and was cut into square pieces of convenient size for coating with dry sugar crystals or chocolate, or the hot jelly was cast in starch molds and allowed to solidify.

Some of the pieces were coated by hand dipping, and the remainder by means of an enrobing machine. The finished product kept well and proved popular with the candy-consuming public.

Jelly candies coated with dry sugar crystals are produced commercially. A stiff pectin jelly, usually without fruit in any form, is made and cast in a slab about ½ in. thick. It is then allowed to cool and harden. It is next cut into rectangular pieces and rolled in coarse sugar. The pieces are allowed to air-dry several days before packaging.

Bursting of the chocolate coatings occurred when the fruit was concentrated to 218 to 219°F., but little difficulty from bursting was encountered in centers previously concentrated to 222°F. or above. It is desirable to allow the cut pieces of jellied fruit to dry in the air for 2 or 3 days before coating with chocolate.

The jelly was also cast in confectioner's starch molds in the same manner as ordinary gumdrops. On standing 24 hr., the cast pieces were separated from the starch and coated with chocolate or with coarse sugar. In the latter case the pieces were moistened with a wet towel and rolled in coarse confectioner's sugar.

A typical formula used in semicommercial tests is as follows:

	Pounds
Fruit pulp	50
Cane sugar	45
Invert sirup	45
Powdered pectin, 150 grade	1.5
Citric acid	0.5

Dissolve the pectin by mixing it with 10 lb. of the cane sugar and adding it to about 2 gal. of water at 130 to 140°F., stirring, and finally boiling a short time. Dissolve the acid in 1 pt. of hot water.

Add the pectin solution to the fruit in a jelly kettle. Mix well. Add the remaining sugar and invert sirup. Boil to 222°F., that is, to a boiling point 10°F. above the boiling point of water for the locality. Add the citric acid solution at this point. Stir well. Cook to 223°F. and cast in starch or pour on an oiled slab to harden.

Other fruit candies are described by Cruess and O'Neill, Cruess and Pen Ho, Cruess, Friar, and Shearing, and by Binder (see references). The author believes that there should be an important market for low-priced fruit candies because of their healthfulness as well as for their pleasing flavor.

Use of Dried Fruits in Candies. Dried fruits require no further concentration in most instances when used in candy. Raisins are in general use by confectioners for the preparation of chocolate-coated clusters, in which peanuts may be mixed with the raisins.

Raisins are also ground to a paste and mixed with chopped nuts and formed into pieces of convenient size, which are then dipped in chocolate.

Dates and prunes are frequently pitted and stuffed with fondant or nut meats. These fruits also yield a satisfactory candy when ground to a paste, mixed with fondant or chopped nuts, and dipped in chocolate. Many dried fruits can be chopped and mixed with nougat candy successfully.

Coconut blends well with dried fruits such as raisins, chopped figs, apples, prunes, apricots, or peaches. Binder developed the following satisfactory formula:

Ingredients. Corn sirup (confectioners') 12 lb.; sugar (cane or beet) 12 lb.; vegetable fat (confectioners') 10 lb. 8 oz.; midget-size seedless raisins or chopped dried fruit 17½ lb.; water 12¾ lb.; lecithin ½ oz.; salt 2 oz.; vanilla to taste; coconut (confectioners') 10½ lb.

Procedure. Cook the water, sugar, salt, coconut, and vanilla slowly to 230°F. Turn off the heat and add the fat and the lecithin. Mix thoroughly.

Then add the raisins or chopped dried fruit and mix very thoroughly. Spread on an oiled slab sprinkled with rice powder or starch. Allow to harden. Cut into pieces of desired size and shape. Enrobe (coat) with confectioners' milk chocolate.

Flavoring of Cream Centers with Fruits. Cream centers for chocolates are generally flavored artificially and colored with permissible coal-tar colors. It has been found that highly concentrated fruit pulp or fruit sirup can be employed for this purpose to produce centers for chocolate coating that are superior in flavor and general quality to the imitation products made without the use of fruit.

Manufacture of Candy Bases from Fruits. Fruit-products factories could, with profit, investigate the manufacture of fruit sirups, fruit jams, jellified fruit products, and dried-fruit preparations for the use of confectioners. Probably such products would provide a large outlet for surplus fruits as well as improve the quality of candies.

REFERENCES

ABELL, T. H.: Apple candy, *Utah Expt. Sta. Bull.* 179, 1921.

ATKINSON, F. E., and STRACHAN, C. C.: Siruping equipment for cherries, *Fruit and Vegetable Processing Lab., Summerland, B.C., Canada, Agr. Expt. Sta. Rept.*, 1954. Mimeographed.

——— and ———: Candying of fruit in British Columbia, *Fruit Products J.*, **20**(5–10), 132–135, 166–169, 199–201, 229–232, 262–264, 289, 291, 310–312, 323, 324, January–June, 1941.

——— and ———: Bleaching, dyeing and glacéing of cherries, *Food Manuf.*, August, 1936.

BARKER, B. T. B., and GROVE, O.: Sulfur dioxide as a preservative for fruit, *J. Pomol. Hort. Sci.*, **5**, 50, 1925.

BINDER, R.: Raisins for new candy ideas, *Mfg. Confectioner*, April, 1954.

California Fruit Growers Exchange: "Confectioners Handbook," Ontario, Calif., 1948. Formulas for jelly candies.

CAMPBELL, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

CENTRAL FOOD TECHNOLOGICAL INSTITUTE: "Fruit and Vegetable Preservation in India," Mysore, India, 1956.

CHACE, E. M., VON LOESECKE, H. W., and HEID, J. L.: Citrus fruit products, *U.S. Dept. Agr. Circ.* 577, November, 1940.

CRUESS, W. V.: Utilization of fruits in food products, *Food Technol.*, **9**(9), 419–426, 1955.

———: Jellied fruit candies, *Fruit Products J.*, **25**(6), 166–168, February, 1946.

———: Utilization of fruits in the candy industry, *Fruit Products J.*, **19**(6), 164–166, 174, February, 1940.

———: Maraschino cherries, *Fruit Products J.*, **16**, 263–265, 277, 279, 281, 283, May, 1937.

———: Splitting of cherries in brine, *Fruit Products J.*, **14**, 271–272, May, 1935.

——— and GLICKSON, D.: Observations on brining and candying of citron peel, *Fruit Products J.*, **12**(11), 17–19, September, 1932.

CRUESS, W. V., and HENRIQUES, V. F.: Experiments on storage of cherries in brine, *Fruit Products J.*, **11**(8), 231–233, April, 1932.

——— and NOUTY, A. H.: Studies on the preservation of fruits in sulfurous acid solutions, *Fruit Products J.*, **6**, 18–20, July, 1927.

——— and PEN HO, F.: Home made fruit candies, *Univ. Calif., Coll. Agr., Circ.* 175, June, 1951.

FELLERS, C. R.: Chemical composition and fermentation studies on citron, *J. Agr. Research*, **53**, 859–867, 1936.

FRIAR, H. F., SHEARING, T., and CRUESS, W. V.: Fruit candies with pectin, *Candy Ind.*, Apr. 27 and May 11, 1946.

JACOBS, M. B.: "Chemistry and Technology of Food," vol 2, pp. 1431–1561, Interscience Publishers, Inc., New York, 1951.

JANG, R., and CRUESS, W. V.: Experiments on the candying of fruits, *Fruit Products J.*, **28**(8), 229–231; 248, April, 1949.

JEFFREY, R. N., and CRUESS, W. V.: Effect of hydrogen ion concentration on the dyeing of cherries, *Ind. Eng. Chem.*, **21**, 1268, December, 1929.

MCCULLOCH, LUCIA: Curing and preserving citron, *U.S. Dept. Agr. Circ.* 13, 1925.

MORRIS, T. N.: "Principles of Fruit Preservation," Chapman & Hall, Ltd., London, 1933.

MRAK, E. M., CAMPBELL, S. V., and ROYER, H. P.: Barreling fruits in SO_2 solution for export, *Food Inds.*, November, 1934.

PACRETTE, J.: "The Art of Canning and Preserving," 1901. Out of print.

POTTS, A. T.: The fig in Texas, *Texas Agr. Expt. Sta. Bull.* 208, 1917.

REED, H. M.: Improved methods of utilizing the magnolia fig, *Texas Agr. Expt. Sta. Bull.* 483, 1933.

RIGBY, W. O., and RIGBY, F.: "Reliable Candy Teacher," Rigby Publishing Company, Topeka, Kans., 1920.

THOMAS, C. C.: The Chinese jujube, *U.S. Dept. Agr. Farmers' Bull.* 1215, 1924.

"The Use of Nutrl-Jel Powdered Apple Pectin," Speas Manufacturing Company, Kansas City, Mo., 1936 (or later edition).

WEAST, C. A.: Dyeing maraschino cherries with erythrosine, *Fruit Products J.*, **20**(11), 332–334, July, 1941.

———: Preparation of solution to be used in brining cherries, *Western Canner and Packer*, 1940, pp. 26–28.

WILLIAMS, C. T.: "Chocolate and Confectionery," Leonard Hill, Ltd., London, 1953.

WOODROOF, J. G., and CECIL, S. R.: Good jams can be made from SO_2 treated fruits, *Food Inds.*, June, 1943.

———, ———, and THOMPSON, H. H.: Preserving fruits with sulfur dioxide solution, *Fruit Products J.*, **22**(5–9), 132–135, 166–169, 202–205, 237–241, 269–272, January–May, 1943.

CHAPTER 16

TOMATO PRODUCTS

The most important relish used on the American table is tomato catsup. Southern European peoples, particularly the Italians, use a large quantity of tomato paste, a highly concentrated tomato product, of which there was formerly a large importation into the United States from Italy. Canned tomato purée is very generally used in restaurants and hotels for flavoring and for soups. Canned tomato soup is one of the best-known soup stocks used in the American home. Hot sauce and chili sauce are much in favor, and in recent years canned tomato juice has become very popular.

DEFINITIONS

A joint committee representing the Association of American Dairy, Food and Drug Officials, the Association of Official Agricultural Chemists, and the U.S.D.A. has promulgated specifications for most tomato products. These standards are followed by pure food and drug officials in the enforcement of the pure food and drug regulations and often form the basis for contracts between manufacturers. The definitions adopted are as follows:

a. **Final Definitions and Standards for Strained Tomatoes and Tomato Paste.** 1. *Strained tomatoes* is the product obtained by straining sound ripe tomatoes, raw or cooked, through a screen that removes skins and seeds.

2. *Tomato paste* is strained tomatoes concentrated by evaporation with or without the addition of salt, and with or without the addition of basil leaf, and contains not less than twenty five per cent (25%) salt free tomato solids, determined by drying *in vacuo* at 70°C.

3. *Heavy tomato paste* contains not less than 33 per cent of salt free tomato solids. Paste of medium concentration contains from 29 to 33 per cent of salt free tomato solids; and light paste, 25 to 29 per cent.

4. *Strained tomatoes from trimming stock* is the product obtained by straining sound peelings, trimmings and pieces from ripe tomatoes through a screen that removes skins and seeds.

5. *Tomato paste from trimming stock* is strained tomatoes from trimming stock

concentrated by evaporation, and otherwise the same as definition (2) above.

6. *Concentrated or heavy tomato paste from trimmings* is made from strained tomatoes from trimming stock concentrated and is otherwise the same as definition (3); similarly for paste of medium concentration.

b. **Tentative Definition and Standards for Tomato Pulp, Purée, Catsup and Chili Sauce.** In the text which follows, the words "strained tomatoes" wherever used refer to strained tomatoes as previously defined:

1. *Medium tomato purée* is the product obtained by evaporation of strained tomatoes, with or without the addition of salt and contains 10.7 to 12 per cent of salt free tomato solids.

2. *Heavy tomato purée* produced as above contains 12 to 25 per cent of salt free tomato solids, and light purée contains 8.37 to 10.7 per cent.

3. *Ketchup, catsup, catchup* is the clean, sound product made from properly prepared strained tomatoes with spices, salt, sugar and vinegar, with or without onions and garlic, and contains not less than twelve per cent (12 per cent) of tomato solids.

4. *Chili sauce* is the clean, sound, cooked product made from chopped, peeled, ripe tomatoes, chopped peppers, salt, sugar, spices and vinegar, with or without onions and garlic. [Per cent of tomato solids not defined.]

c. **Tomato Juice** is the unconcentrated pasteurized product consisting of the liquid with a substantial portion of the pulp, expressed from ripe tomatoes with or without the application of heat and with or without the addition of salt.

The Committee also established tentative standards for the various grades of purée from trimming stock, which correspond in per cent total solids to the percentages given above for purée from strained tomatoes.

TOMATO COLOR

Tomato products should have a deep-red color, a quality which varies with the variety, the locality, maturity of the fruit, and process of manufacture.

Nature of Tomato Color. Tomato color was first separated in pure form in 1876 by Millardet, who named it "solanorubin." It was again isolated by Schunck in 1903, who named it "lycopene," a name generally applied to it today. Montanari proved that it is a hydrocarbon, and Willstätter and Escher have proved that lycopene is an isomer of carotene (also formerly spelled carotin and found in tomatoes). Lycopene can be extracted from tomato pulp by ether or carbon bisulfide, and the crystals obtained by evaporating *in vacuo* an ether or carbon bisulfide solution of the pigment are dark to light carmine-red in color and of waxy consistency. The crystals when pure melt at 168°C. and possess the empirical formula $C_{40}H_{56}$. Lycopene rapidly oxidizes in contact with air and fades in color.

Preserved in hydrogen, nitrogen, or carbon dioxide, it retains its color indefinitely.

Duggar states that in the absence of lycopene, the flesh of the tomato is yellow, owing to carotene and possibly xanthophyll, which are masked in the red fruit.

Color Changes during Ripening. According to Hanson, the deep green of the chlorophyll first fades to a greenish white during ripening, which is followed by the development of a yellow or light orange color. Under the microscope yellowish granules and orange crystals can be found in the parenchyma cells at this stage of the ripening process.

As the red color becomes apparent, dark or light carmine-red needlelike or prismatic crystals of lycopene appear. These become grouped in bundles as the color becomes more intense and the yellow pigment decreases in amount.

Effect of Manufacturing Processes on Color. The quality of tomato products depends to a large degree upon the color, and retention of the natural red color is one of the most important problems in the manufacture of tomato products.

Chlorophyll, the green pigment of unripe tomatoes, turns brown during cooking, thus greatly reducing the intensity of the natural red color, and if green fruit is used in excessive amounts, the color of the product will be brown or brownish red. Careful sorting will eliminate green fruit.

Tomato products should not be permitted to come in contact with iron because it causes lycopene to turn brown; and iron salts in catsup and other spiced tomato products combine with tannin from the spices to form iron tannate, a black compound, which may darken the color of the entire contents of the bottle or may form a dark deposit near the surface of the bottled product.

Copper salts also are injurious to tomato color; hence the desirability of using glass-lined or stainless-steel equipment.

Prolonged heating causes lycopene to become brown, and the cooking and concentrating processes should be accomplished as quickly as possible if a product of bright red color is desired. High temperatures are also harmful to the color, according to MacGillivray. For this reason concentration *in vacuo* usually yields a product of better color than concentration in an open kettle.

Cooling of the sterilized product should be prompt and thorough. Stack burning of insufficiently cooled canned tomatoes has been a frequent cause of poor color.

Munsell Color System. The color of tomato products can be measured quantitatively by the apparatus and according to a procedure originally devised by A. H. Munsell. In brief, the method consists in comparing the color of the product with that of a whirling disk made up of cardboard

segments of various colors, the segments being interchangeable and adjustable in respect to area exposed; or the eyepiece of the instrument may be revolved, and the color disk then is stationary. The method may be applied also to measuring the color of many opaque products, such as cotton fiber, hay, tobacco, butter, etc.

According to this system, color is understood to have three principal attributes, viz. (1) chroma ("strength"), (2) hue (tint, as red, pink, etc.), and (3) value (brilliance). The Munsell method is well described by Nickerson (see also Cleland).

The spectrum is divided into 10 hues ranging from R (red) through YR (yellowish red), Y (yellow), etc., to RP (reddish purple). Each hue is also divided into 10 divisions with numerical values of 1 to 10; thus 5R is midway in the R section of the spectrum.

In expressing results in this system, hue is represented as above by some such designation as 5R; value is expressed by the number above the line in the fraction, and chroma by the number below the line. Thus 5R 3/2 means that the hue is that of the middle of the red section of the spectrum, the "value" is 3, and "chroma" is 2 on their respective scales. In expressing the color of tomato products, the hue YR also is used with the hue R, supplemented by so-called "neutral" disks. N1 is nearly black and N4 is gray; these are the neutral disks used with the R and YR disks to match the color of tomato products. Thus the minimum color for Fancy and Standard tomato products is 5R 2.6/13 glossy finish and 2.5YR 5/12, N1/and N4/ (for further details of this system see Nickerson or Cleland).

The equipment used in canneries usually consists of a metal disk to which may be attached paper disks of the colors such as R, YR, N1/, etc., to be used for any given product. The area of each paper disk to be exposed can be varied at will. The metal disk is attached to a small variable-speed electric motor. The sample is placed in a dish beside the rapidly whirling color disks. The exposed areas of the different disks are varied until a color match is obtained. The area of each color exposed is then measured in per cent of total area of the disk.

The **Agtron Color Instrument.** When tomatoes are delivered by the grower to a tomato-products establishment they are usually inspected not only by the plant's quality-control staff but also by a state or Federal inspector for various factors, including color. The tomatoes are graded for color by comparison with carefully prepared color photographs, and the inspectors are carefully trained and closely supervised. In spite of such precautions disagreements have arisen in the past concerning the proper classification of borderline samples. Similarly, disagreements have arisen between manufacturers of tomato products and purchasers of large lots of various tomato products, particularly purée or paste for remanu-

facture. A simplified objective color-measuring instrument was needed for quickly and accurately measuring the color of the raw product and various finished tomato products. A great deal of attention was given to this problem by the food technologists of Ohio State University, investigators of the U.S.D.A., and staff of Magnuson Engineers of San Jose, California, in the period 1950 to 1954. Partly as a result of these cooperative studies and of investigations made in California by Magnuson Engineers, in consultation with the Huggins Laboratories of Menlo Park, California, an instrument known as the Agtron, Model F, was developed by Magnuson Engineers. It was originally developed for the U.S.D.A. for measuring the color of extracted pulp of raw tomatoes to establish a color grade for the fresh tomatoes.

As described by the manufacturer, the Agtron embodies a gas-discharge light source for illuminating the sample, a Corning glass filter for isolating a selected monochromatic line of the source, and a vacuum phototube and electronic amplifier for measuring the reflected monochromatic illumination. It is provided with a meter calibrated from 0 to 100. Two different reference materials are used to standardize the instrument, one having a color somewhat darker than the darkest sample to be controlled and the other a little lighter than the lightest sample. By means of separate controls the instrument is adjusted so that it reads zero (0) with the dark standard and 100 with the light standard. With the instrument used in the Food Technology Department of the University of California, the dark standard is a black plastic disk and the other is a disk of light red color that is somewhat lighter in color than that of tomatoes or a tomato product of minimum acceptable color. The instrument is set to read 100 with the latter disk and 0 with the dark disk. Therefore the higher the reading for a given sample, the lighter will be its color. According to Luh of this department, a good color for fresh tomatoes is 40 to 50 on the scale and 70 would be unacceptable. However, for in-plant quality control of the color of such products as paste, purée, and catsup the cannery's laboratory personnel can set up its own scale for optimum, minumum, and maximum color standards as measured by the Agtron, using previously selected samples for comparison.

By use of the standard disks for establishing the 0 and 100 readings of the instrument's scale, readings on the same sample on different Agtron instruments in several laboratories are comparable. If the color of a fresh tomato is to be measured, it is cut in half and the two halves are placed in spring-supported cradles which fit inside a housing in the instrument. The halves are placed directly beneath the phototubes, which view the samples first through a red and then a green Corning glass filter, while low-pressure neon and mercury vapor lamps illuminate the samples. By comparing the reflectance of the two lines the ripeness of the tomato can

be judged. For the guidance of inspectors the scale is divided into three sections labeled Well Colored, Fairly Well Colored, and Below Color (culls).

If a tomato product is to be examined, it is placed in a shallow glass or plastic cup, resembling a deep Petri dish, and this is placed in position in the instrument for examination by reflected light. Gould (1954), of Ohio State University, states that by use of a special cup the product to be examined, such as juice or purée, can be passed continuously through the cup and many measurements made during the day or a continuous record made by recording instrument.

The instrument is in very general use by inspectors of the U.S.D.A. and California State Department of Agriculture as well as many manufacturers of tomato products. According to Gould (1954), it has been used for color measurement and control for other food products such as baby foods, breakfast cereals, spices, roasted ground coffee, starch, brewers' malt, citrus concentrates, and ground chocolate.

Other Color-measuring Instruments. Spectrophotometers equipped for reflectance measurement can be used to measure the depth of the dominant colors existing in tomatoes or tomato products. Recording instruments of this type are available. The Hunter color and color-difference meter described by Younkin (1950) and by others has been used by Kramer (1950), Younkin (1950), Robinson, Ransford, and Hand (1951), Mackinney, and by other investigators for the measurement of the color of tomatoes and tomato products. It is a trichromatic instrument. In trichromatic examination of color its characteristics are specified in terms of three-color constituents; ordinarily the three chosen are red, green, and blue. The proportions of each and the total luminosity are adjusted until a match is obtained for the color of the sample examined. According to Robinson et al. (1951), very good agreement is obtained between the color grade assigned to tomato-juice samples by experienced inspectors and that determined by the Hunter instrument. The trichromatic system of color specifications was adopted in 1931 by the International Commission on Illumination for standard reference. The Guild Trichromatic Colorimeter and the Photovolt photoelectric reflectometer are other forms of trichromatic instruments. Worthington, Cain, and Wiegand (1949) and Friedman, Marsh, and Mackinney (1952) have used the Photovolt reflectance meter for measuring the color of juices and tomato products. See Worthington et al. for a description, with illustrations, of this instrument. Desrosier, (1954) reports that the Purdue photoelectric color meter, developed at Purdue Univeristy, which measures the ratio of red to yellowish green (640 mμ/560 mμ) in tomatoes and tomato products, has proven very satisfactory. Results agree closely with those obtained with the Hunter instrument and the visual color grading of experienced inspectors.

TOMATO PURÉE

Certain tomato products are made from tomato pulp, which represents the unflavored, finely divided flesh and juice separated from skins and seeds. It is usually concentrated to a greater or less degree before use in other products or for canning.

Tomato Varieties for Purée. Tomatoes for purée, catsup, sauce, and other tomato products should be of smooth skin and free from wrinkles and folds and should have a shallow stem cavity so that molds and other organisms may not accumulate in such cavities. They should be of deep red color with firm flesh and small seed cavity and should ripen evenly. Size is not so important as in canning because the tomatoes are not peeled (except for chili sauce).

In California the Pearson is now the most important variety grown for canning and manufacture of tomato products. It is a heavy bearer, possesses good color and flavor, and need not be picked as often as some varieties. Under irrigation it has given yields in excess of 20 tons per acre. Formerly the Santa Clara Canner was grown extensively, but in central and northern California it has been replaced almost entirely by the Pearson. The Moran is another heavy-bearing variety grown in the Sacramento Valley for canning and products. In southern California the Norton, a selection of the Stone, is grown, as it is resistant to a tomato-plant disease of the region. The San Marzano, a pear- to plum-shaped small tomato, originating in Italy, is grown very extensively for the production of tomato paste because of its firm pulp and deep color. See Chapter 10, Canning of Vegetables, for names of other varieties suitable for canning and tomato products.

Picking, Transporting, and Storing. Even greater care must be observed in picking, transporting, and storing tomatoes for purée, etc., than for canning, because the former are not peeled. Boxes should be washed frequently and not allowed to become moldy. The fields should be picked daily during the height of the ripening season to avoid gathering of unripe and overripe tomatoes. They should be transported to the plant without delay in order to avoid mold growth, and for the same reason the tomatoes should be utilized immediately upon arrival at the plant. In California 50-lb. lug boxes are used, but in other states baskets are apt to be the usual containers.

The first, and probably the most important, requisite to success in tomato-products manufacture is the use of sound raw material. The manufacturer must be particularly careful in the inspection of deliveries of tomatoes following heavy rains or during prolonged periods of damp weather. Rains cause splitting of the fruit, with subsequent rapid develop-

ment of mold. High mold counts were once the most frequent cause for rejection or condemnation of tomato products, but content of worm and insect fragments has assumed greater prominence recently.

Inspection. In California inspectors of the State Board of Health as well as the canneries themselves examine each load of tomatoes for mold and

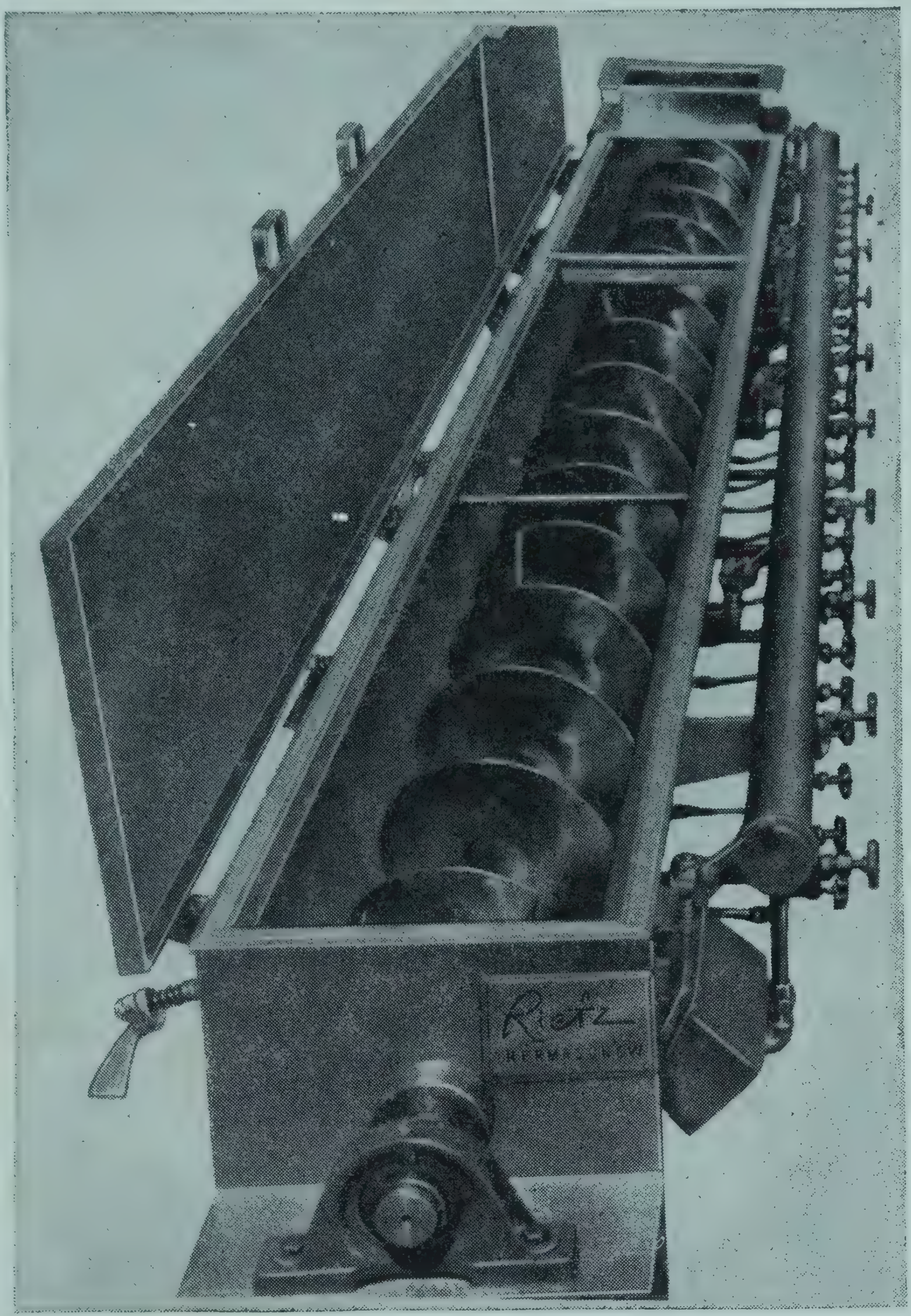


FIG. 73. Rietz thermoscrew blancher, used either with steam or hot-water blanching of fruits and vegetables. Model TL, 12-K22 15. (*Rietz Disintegrator Co., Santa Rosa, Calif.*)

worm damage and presence of green, sunburned, and other defective tomatoes mentioned in the following definition of U.S. No. 1 tomatoes.

The purchase of tomatoes on the basis of U.S. grades has been followed in some canneries. As defined by the Bureau of Agricultural Economics of the U.S.D.A.:

U.S. No. 1 shall consist of tomatoes which are firm, ripe, well colored and formed, free from molds, decay and from damage caused by growth cracks, worm holes,

cat faces, sun scald, injury in freezing, mechanical or other cause. U.S. No. 2 is defined as tomatoes which do not meet the requirements for the foregoing grade, but which are ripe and fairly well colored and which are free from serious damage from any cause. Culls are tomatoes which do not meet the requirements of the foregoing grades.

Size is usually left to mutual agreement between the canner and the grower.

The results of a commercial-scale survey in Indiana showed that fewer green tomatoes, less rotten, and more red-ripe, sound tomatoes can be secured by this method than by the usual "let-alone" method. A sufficiently higher price should be paid to the grower for No. 1 tomatoes to pay for the extra cost of growing and picking. This would serve as an incentive for production of tomatoes of higher quality and enable the canner to make finished products of higher quality.

Washing. The tomatoes should be thoroughly washed before sorting because the work of the sorters is thereby made more effective. Any of the devices described for washing tomatoes for canning may be used; the rotary washer is one of the most effective.

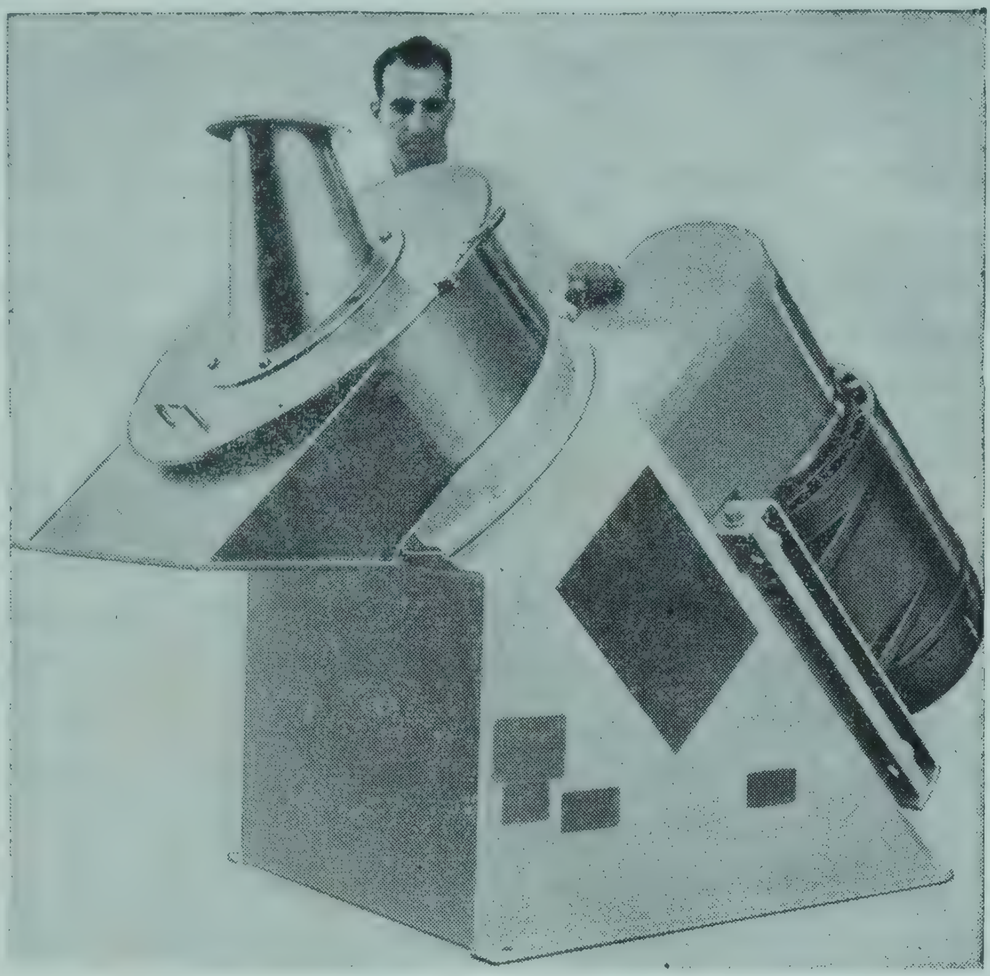
According to B. J. Howard of the U.S.D.A., a rotary heavy-wire or fluted sheet-metal cylindrical washer, inclined at an angle of about 1 ft. in 8 and equipped with an abundance of water under heavy pressure, may be used. The screen, or fluted surface, causes the tomatoes to roll, whereas they may merely slide if the cylinder is made of smooth perforated sheet metal. He states that a cylinder 2 to 2½ ft. in diameter and 8 ft. long and revolving at about 20 r.p.m. will satisfactorily wash about 2 bu. of tomatoes per minute. Many rotary washers are larger than this and of correspondingly greater capacity.

Simple agitation in water is not satisfactory, because tomatoes often carry, in cracks and in the stem cavity, mold filaments which agitation does not dislodge and which appear later in the finished product, where they can be found by the microscope of the food inspector or buyer. Heavy sprays of water under very high pressure playing into the soak tank through which the tomatoes are carried in water will remove a large proportion of such mold filaments and small areas of soft rot not seen by the trimmers and sorters. Sprays more effectively remove adhering clay, dried particles of pulp, etc., from the skins of the tomatoes than does mere agitation in water.

The first requirement of a satisfactory tomato washer is water under heavy pressure, up to 400 lb. per sq. in., driven against the tomatoes in sprays. Agitation during spraying is the second essential. This can be done by roller conveyer or by revolving drum. Modern tomato washers use water at about 400 lb. pressure per sq. in., with the tomatoes being carried by roller conveyer or by metal-cloth conveyer through the sprays.

Efficient and effective washing is one of the most important steps in he manufacture of tomato products. The mold content of the finished rticle is dependent in a very marked degree upon this operation, because, s was stated above, the tomatoes are not peeled before pulping.[1]

The Vinegar Fly Problem. In California, as well as in other important omato-canning areas, vinegar flies have become a very serious pest. They



ɪɢ. 74. Rietz angle disintegrator used for high-speed fine pulping of fruits and vegetables. Model RA-3. (*Rietz Disintegrator Co., Santa Rosa, Calif.*)

eproduce rapidly and in enormous numbers in the field in broken tomatoes, iles of waste fruit, pomace piles near wineries, and in other favorable ocations. They swarm around boxes or baskets of picked tomatoes and ay eggs in great numbers on them unless control measures are taken. 'he eggs may carry through into finished purée, juice, catsup, or other roduct, where they may be detected by microscope. See Chapter 10, 'anning of Vegetables, for additional information and control measures.

Sorting. Howard, who has shown the great importance of careful sorting, nakes the following statement:

> A careful consideration of the causes of failure in making clean, sound sanitary omato products shows clearly that more difficulty is experienced in effecting anitary washing, prompt handling and efficient sorting than in any of the other

[1] The author is greatly indebted to B. J. Howard of the U.S.D.A., Bureau of Chemisry, for much of the material presented on washing and sorting of tomatoes and on plant anitation. After his retirement from the U.S.D.A., Dr. Howard died, several years ago. Iis publications are still used and respected in the industry.

phases of the manufacturing process. Sorting is the most important of these operations, in which judgment of the operator plays an important part. Satisfactory washing is largely a question of proper operation of a mechanical device. This may be said of many of the other operations about the factory, but so far no mechanical device for separating the decayed from the good parts of tomatoes has been placed on the market. This operation must still be performed by hand. In the making of pulp of any kind, efficient sorting is absolutely necessary.

Since sorting is so important, greater care should be exercised in the selection of sorters than in selecting workers for any other operation.

Because of the close attention necessary, this work is very fatiguing, and the workers should be employed in short shifts of not over 3 hours each. Sorting should be in charge of an experienced person who has proved his or her efficiency in this work and who is alert and discriminating as well as able to tactfully direct the other workers.

Sorting Systems. Various sorting systems are in use. These may be designated as (1) table, (2) simple apron, and (3) divided apron.

In the table system of sorting, which is no longer used except in very small plants, the tomatoes are dumped upon a stationary table from the box or basket. The badly decayed tomatoes are rejected, and small pieces of rot are trimmed from the fruit. The sound tomatoes are placed in suitable containers, such as buckets or pans, and transferred to the washer. The work of individual sorters can be effectively observed and controlled where this system is used, but it is usually more expensive than other methods. Sorting is usually done after washing.

In the simple-apron sorting system, the tomatoes are carried on a broad and slowly moving belt before the sorters, who remove unfit material and permit the sound fruit to pass over the end of the belt to the washer and pulping machines. Theoretically, the tomatoes are subjected to as many sortings as there are workers at the apron, and this is practically true if the speed of the belt is not too great, if the belt is not overloaded, if the sorters are efficient, and if the apron is properly lighted. The apron should be narrow enough for the sorters to reach across the entire width, the most convenient width being about 18 to 20 in.

In the divided-apron system, the tomatoes are placed upon a conveying apron divided by lengthwise partitions into three alleys. The tomatoes are carried in the two outside sections. The sorters place the sound fruit in the central section and allow the unfit material to pass over the end of the belt through the outside sections. In some cases the rotten fruit is placed on the central conveyer and the sound fruit in the outside sections. Practically every tomato must be handled. Although this is an effective method of sorting, it is more expensive to operate than the simple apron.

The modern sorting "belt" is made of bronze or stainless-steel rollers

that turn by friction and roll the tomatoes over and over as they are conveyed forward, thus permitting very effective sorting.

Proportion of Moldy Fruit to Be Removed. Howard, in reporting the results of 100 tests in 30 factories east of the Mississippi River, states that the proportion of moldy tomatoes (wholly or in part) in unsorted fruit varied from 0.4 per cent to 81 per cent and that the average was about 25 per cent. This means that about 58 tomatoes must be removed or trimmed from each bushel. California tomatoes normally contain less moldy fruit than this.

Rate of Movement of Apron. The speed of the apron should be slow enough for the sorters to recognize and remove or trim all tomatoes containing rot and should not exceed 25 ft. per min. Howard reports speeds of from 16 to 140 ft. per min. in various factories.

Volume of Fruit Sorted. A bushel of tomatoes (about 60 lb.) covers, according to Howard, from 7 to 12½ sq. ft. and an average of about 9⅓ sq. ft. Experience has shown that not more than one-half of the area of the belt should be covered in order to permit effective sorting. Therefore a space of at least 18½ sq. ft. should be allowed for each bushel in designing the sorting belt for a given plant. A belt 18 in. wide and moving at a rate of 25 ft. per min. would have, on this basis, a capacity of about 120 bu. per hr., or 1,200 bu. (36 tons) per 10 hr., and would require the services of six sorters.

Under average conditions of table sorting, one sorter can care for 5 to 8 bu. (about 300 to 500 lb.) per hr. and in apron sorting 20 to 25 bu. per hr. A rate of 25 bu. per hr. should be considered the maximum for efficient sorting. These values refer to plain sorting belts; the new roller sorting belt has somewhat greater capacity.

The tomatoes should be fed to the sorting belt at a uniform rate of speed. The custom, observed in some factories, of dumping several boxes of tomatoes on the apron at irregular intervals causes the belt to be overloaded for short periods and empty during the interval between dumpings. Fairly satisfactory feeding hoppers are now obtainable and should be used to regulate the rate of flow of tomatoes to the apron. The tomatoes should not be heaped on the belt, but should be only one layer deep and not crowded tightly together.

Turning. In many factories the sorting aprons are equipped with turning devices that automatically turn the tomatoes so that all portions of the surface of the fruit can be inspected by the sorters. One form of turning device consists of several pieces of water pipe, ¾ to 1 in., about 7 in. long, suspended from a steel rod above the sorting apron. The pipes are free to swing in the direction of flow of the apron. As the tomatoes pass beneath the pieces of pipe, the weight of the latter is sufficient to turn the fruit.

Howard has found that not more than 50 per cent of the area of t[he] apron should be covered with tomatoes in order to give space for t[he] tomatoes to be turned properly. On rubber or canvas belts there is [a] tendency for the tomatoes to slip instead of turn, and the turning devi[ce] operates more satisfactorily on woven metal conveyers. As previous[ly]

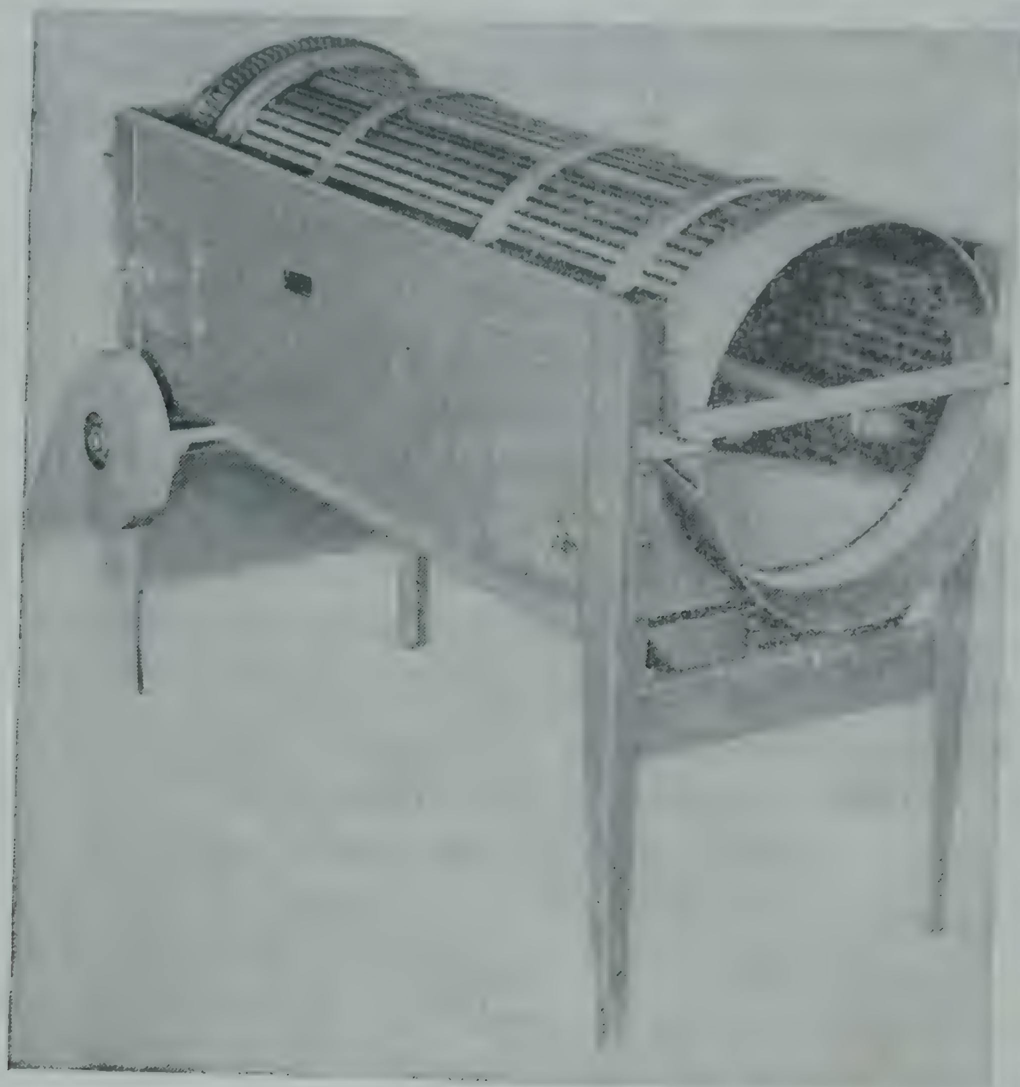


FIG. 75. Drum washer, useful in washing tomatoes and root vegetables. (*Food Machiner[y] Corp.*)

mentioned, the modern roller sorting belt continuously turns the tomatoe[s] if it is not overloaded (Figure 57).

Importance of Proper Lighting. The speed and efficiency of sorting depend to a marked degree upon the lighting of the sorting belt. Effective sorting cannot be done if the sorting apron is located in a poorly lighted corner of the factory or if artificial light is not used on foggy or cloudy days. The lights should be directly above the sorting belt and so placed that the shadows of the workers do not fall upon the fruit.

Effect on Quality of Sorting. Howard has found that the percentage of rotten material in tomatoes delivered to a large number of plants under his observation has varied from practically 0 to over 30 per cent and that the average was about 5.5 per cent. The percentage of rot in the sorted product varied from practically 0 to over 7 per cent, with an average of about 1⅓ per cent. By careful sorting, rotten material should be considerably below this average, and at no time should it exceed 1 per cent.

The proportion of rot is determined by weighing samples of 20 to 50 lb. of the sorted tomatoes direct from the belt and by trimming out and weighing objectionable portions.

Trimming. Many of the tomatoes removed by the sorters can be trimmed, and the sound portions of the fruit salvaged. This is best done by a separate crew.

The canner, however, must not be too zealous in his attempt to salvage by trimming, or he may badly damage the quality of his finished product. Enough of the tomato must be cut away to ensure complete removal of rot and of flesh that has absorbed a disagreeable flavor from the adjacent rot.

Coring. Since inauguration of maximum tolerance for worm- and insect-fragments content of tomato products, some canners have considered coring tomatoes to be used for juice, since small worms frequently are at work in the flesh or stem in or near the core. Coring, incidentally, greatly reduces the mold content of the product. By use of the water-driven Hydrout, described in the chapter on vegetable canning, the cost of coring can be greatly reduced. However, thorough and critical sorting and trimming are followed commercially instead of coring.

Use of Peels and Cores. If tomatoes used in canning are very carefully sorted and trimmed before scalding, the cores and selected trimmings may be used for the preparation of purée, but the sorting to be effective must be done before scalding and cannot be done satisfactorily by the peelers.

Attempts have been made to wash the rot from peels and cores from unsorted fruit, but besides being very ineffective, this procedure results in great loss of tomato juice and pulp.

It is impossible to sort out rotten material from peels and cores, and furthermore, such an attempt contaminates the whole mass of material with soft rot from badly decayed portions.

Pure food and drug officials state that in the majority of cases brought in the past against tomato products, the goods involved were made from trimmings, i.e., peels and cores.

Howard recommends not less than one-eighth as many sorters and trimmers as peelers, if peels and cores are to be used for tomato products, but this ratio will vary greatly with the condition of the tomatoes.

Pulping. The washed, sorted, and trimmed tomatoes are converted into pulp by a machine commonly known as a "cyclone," or pulper. The machine usually consists of a heavy copper, monel, stainless-steel, or bronze perforated sheet or screen in the form of a half cylinder which forms the lower half of the cylinder of the pulping machine. The upper half of the cylinder is of wood or heavy sheet metal. Heavy paddles revolve at a high rate of speed within the cylinder, and the tomatoes are broken by impact of the paddles or by being thrown against the walls of the

pulper. The pulp and juice pass through the screen into a tank, and the skins, seeds, and fiber pass out through an opening at the lower end of the pulper. The tomatoes enter the pulping cylinder through a hopper, usually fed by a continuous conveyer, and the mixture of pulp and juice is pumped to the concentrating kettles or other equipment (Figure 77).

Another pulper consists of an upright cylindrical screen against which the tomatoes are thrown violently by centrifugal force.

Heating. In some factories the present custom is to convey the washed, sorted, and trimmed tomatoes direct to the pulper without preliminary heating. In one system of hot pulping the whole tomatoes are conveyed to a "breaking tank" and cooked with steam coils until thoroughly heated and softened. In some plants the tomatoes are crushed before heating, and the hot fruit is then pulped in the usual manner. In modern plants the tomatoes are crushed and pumped through a steam-jacketed tubular heater, from which they enter the pulper scalding hot (Figures 73 and 78). This method gives a somewhat higher yield of pulp than is obtained by cold pulping and a pulp richer in pectin and gums, which increase the viscosity and decrease the tendency for the pulp and juice to separate. Catsup from hot-pulped tomatoes will "stand up" and not spread when a drop of the catsup is placed upon a blotter, in sharp contrast to that from cold-pulped tomatoes, which flattens and spreads quickly in the "blotter test."

It is doubtful whether hot pulping improves the color of the pulp, but it kills microorganisms and eliminates any increase in their number during normal operation of the plant. It also protects vitamin C and the pectin content of the product by destroying the enzymes responsible for loss of these valuable constituents.

Conveying Pulp to Concentrator. Pumps should be made of bronze or other metals not acted upon to any marked degree by the acid of the tomatoes. Iron and steel become rusty and dissolve in the tomato juice to a sufficient extent to cause darkening of the color.

Pipes through which the pulp is conveyed should also be of material that does not injure the quality of the product. Glass-lined (enamel-lined) iron pipes are resistant to tomato acid and are easily cleaned. Block-tin pipes or silver-lined copper pipes have been successfully used. Wooden pipes have been used quite extensively but are difficult to clean and usually permit development of mold and bacteria during periods of idleness, with subsequent serious contamination of the pulp with these organisms. At present stainless steel and nickel are preferred for pumps, pipelines, and other such equipment.

Pipelines should be cleaned thoroughly at the end of the day by flushing with water and by steaming. Before use in the morning, water should be pumped through them. Pipelines, pumps, and certain other equipment are

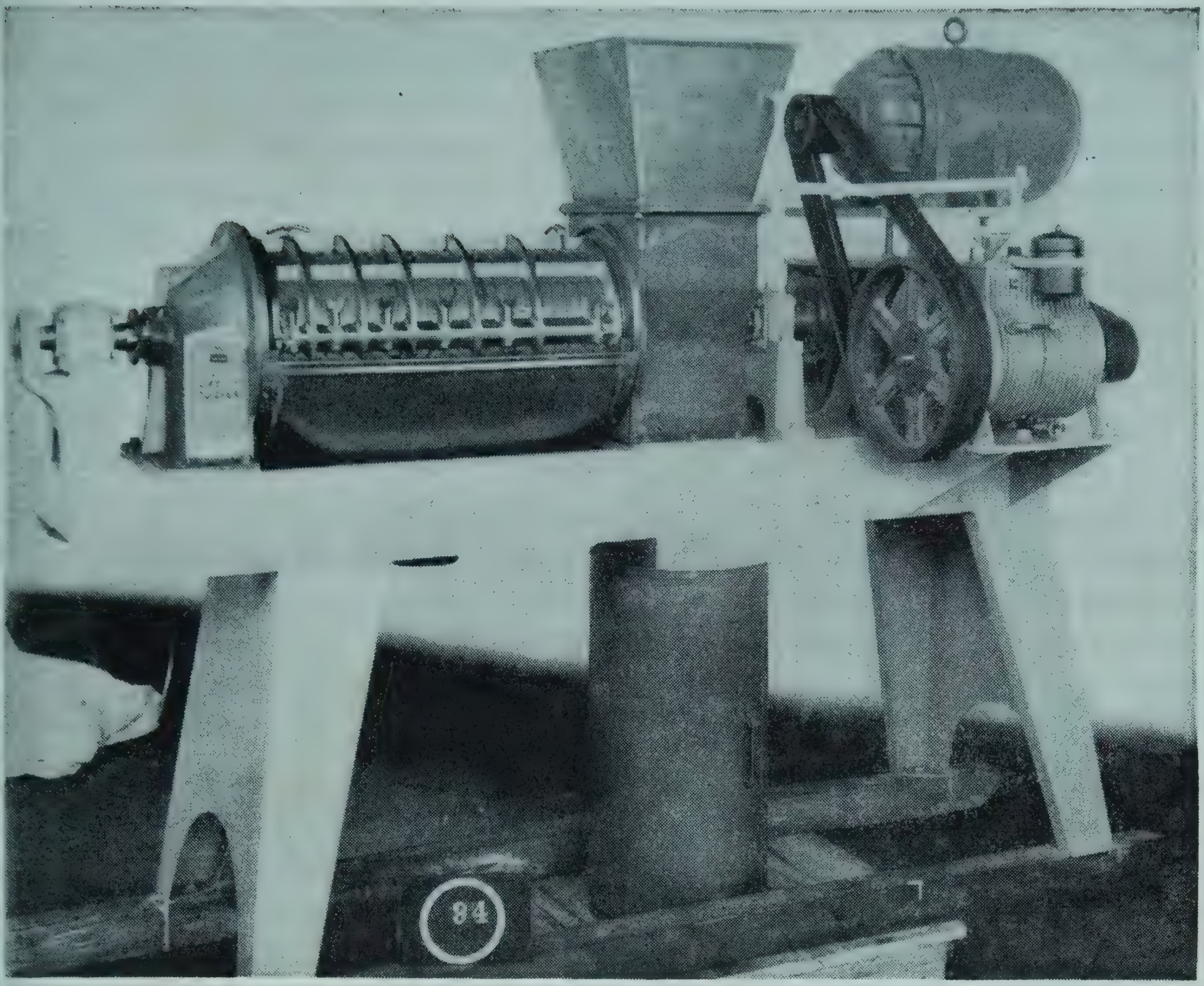


FIG. 76. Large-size Model J tomato-juice extractor. (*Chisholm Ryder Co. and Norton Advertising Service.*)

often prolific sources of infection if not cleaned frequently and thoroughly. Joints should be smooth and not permit of accumulation of pulp and growth of mold.

Concentration of the Pulp. The raw pulp is too thin to be used without concentration and must be evaporated to the desired consistency before canning or using for tomato catsup or other tomato products.

Open Cookers. Open kettles used for concentrating tomato pulp are made of wood, copper, tin-lined copper, stainless steel, or glass-lined steel. The last-named material is readily cleaned.

Open kettles are often not steam-jacketed but are heated by closed copper or stainless-steel coils known as "flash coils." The diameter of the usual flash coil is about 3 in. This relatively large diameter gives a large heating surface, allows free passage of the steam, and allows rapid and uniform heating of the coils, so that local overheating and sticking of the pulp are reduced to a minimum. Such a coil will under normal conditions reduce a charge of 500 gal. of pulp to one-half its original volume in 35 to 45 min. or less.

Wooden Tanks. Cypress is most commonly used for wooden concen-

trators, but wooden tanks are apt to impart a musty or moldy flavor to the pulp unless kept clean and free from mold growth when not in use.

Metal Kettles. Copper kettles are more expensive than wooden tanks or glass tanks equipped with flash coils and have the additional objection that the copper may injure the tomato color. Nickel and monel metal are both more desirable, although more costly than copper. Stainless steel of the proper composition is extremely resistant to corrosion and is therefore very desirable for cookers and also for pulper screens, filling equipment, etc., although costly.

Glass-lined Kettles. So-called "glass-lined tanks" are constructed of an outer shell of steel, lined on the inside with heavy enamel, which is fused into the steel at a high temperature. The surface is smooth and easily washed, and the enamel is practically insoluble in the juice. For these reasons this equipment is preferable to wood and copper. A common size for such tanks is about 1,100 gal., a convenient size for a 600-gal. batch of pulp. However, kettles are now usually of stainless steel.

Vacuum Pans. Vacuum kettles are used in some plants, their principal advantage being in reduction of the boiling point to 160°F. or less, making it possible to retain the color and flavor of the tomatoes to a remarkable degree. They are now very generally used in concentrating tomato pulp to paste. In some cases double-effect or triple-effect vacuum pans are used, giving increased output and conserving steam.

The Peebles descending evaporator used for the concentration of tomato products consists of two vertical, steam-jacketed, stainless-steel tubes of rather wide diameter in series which may be operated at atmospheric pressure or under vacuum. The product flows downward on the inner walls of the first tube and boils vigorously as it travels. It is then pumped to the top of the second tube in which the downward flow and boiling are repeated. Rates of flow and boiling are controlled in such a manner that a purée or other product of the desired total solids content emerges from the second tube.

Vacuum pans of more or less standard type, as described in Chapter 13, are used for the concentration of tomato products. The product is usually heated with steam coils or calandrias. A concentrating unit consisting of three vacuum pans in series is in use in California. Freshly prepared pulp enters the first pan, and the concentrated purée or paste is taken from the third effect. Operation is continuous and automatic. The degree of concentration is controlled automatically.

Cooking the Pulp. In order to prevent foaming and sticking of the pulp to the coils, some manufacturers of pulp add a small amount of cottonseed oil to the kettle, so that as the pulp rises during the filling of the kettle, the sides and coils are coated with oil. There are now available very powerful silicone antifoaming agents, which in a concentration of a few parts

per million prevent foaming. Foaming can be avoided, however, by careful heating and by spraying the surface of the boiling pulp with water occasionally.

As soon as the coil or steam jacket is covered, steam may be admitted and boiling started. During the first stages of boiling, the coil or jacket must be well drained to prevent its filling with water, a condition that favors scorching.

Concentration must be accomplished rapidly in order to retain the bright red tomato color and fresh flavor. A boiling of 30 min. is usually sufficient in a tank equipped with a good flash coil and an adequate supply of steam under high pressure.

Determining the Finishing Point. Manufacturers of partially concentrated tomato pulp (purée) experience considerable difficulty in obtaining a finished product of uniform composition and in determining accurately the point at which to stop the boiling process.

The pulp is usually concentrated to, and sold upon, a definite specific gravity, such as 1.045 or 1.04.

Concentrating to Definite Volume. Bigelow and Fitzgerald, and later Bigelow, Smith, and Greenleaf, therefore recommend concentration of a measured volume of the raw pulp to a definite volume of concentrated purée. In boiling tanks with straight sides the volume may be determined by a measuring stick, due allowance being made for the volume occupied by the heating coil. A more accurate method is to calibrate the tank by adding measured volumes of water. The specific gravity and temperature of the raw pulp from the pulping machines are determined accurately. From these data and Table 6 of *National Canners Association Bulletin* 27-L, the volume to which the pulp must be concentrated is determined.

By Specific Gravity. In some factories the specific gravity of the pulp during the boiling process is determined and the end point estimated on this basis. However, such rapidly made determinations are liable to be very inaccurate, for reasons noted below. Even if done accurately, they cannot be made quickly enough to be of very great value to the operator of the kettle.

Table 4 of *National Canners Association Bulletin* 27-L gives the factors necessary for correction of specific gravity of the pulp determined at other temperatures than 68°F.

By Refractometer. Most canners now determine the end point by use of an Abbe refractometer, as described later in this chapter. It is rapid, dependable, and accurate.

The manufacturer of tomato products must make accurate determination of the specific gravity or total solids by refractometer of each lot as it is finished in order that he may know that it is of the desired density or solids content. If the concentration is too high, specifications will be

exceeded and loss incurred thereby; if it is too low, the buyer will have grounds for rejection or for complaint.

Specific Gravity Methods. Several methods are in use in tomato-products factories for the determination of specific gravity. The more important are given below.

Sprague Cup Method. The most common method of determining the specific gravity of tomato pulp was formerly by use of the Sprague cup and balance. The cup is a conical copper vessel holding 1 liter. This is filled

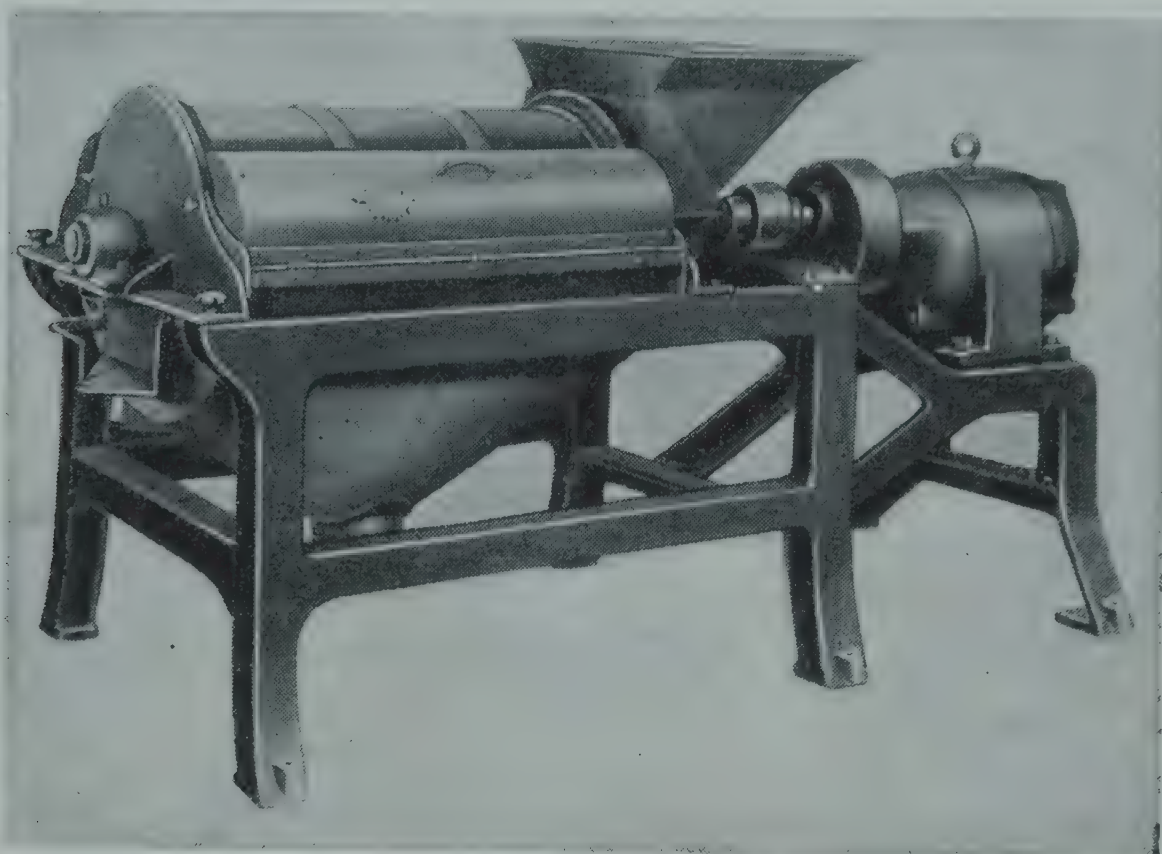


FIG. 77. Fruit and tomato pulper. (*Sprague-Sells Machinery Corp.*)

level-full with boiling water, the outside is dried carefully, and the cup with contents is weighed. It is again weighed level-full of the boiling hot pulp. The scale is so constructed that the weight of the empty cup is counterpoised, and the ratio of weight of the pulp to that of the water gives the specific gravity of the pulp.

In filling the cup, the pulp cools somewhat, which will cause its specific gravity to increase. Air may be trapped in the pulp and cause it to weigh less than it should. Although these are compensating errors, one or the other frequently causes very serious inaccuracies in the determination. Bigelow and Fitzgerald have found that very much more reliable results are obtained by immersing the cup in the hot pulp in the boiling tank and leveling off the surface of the pulp at once. This reduces to a minimum both the errors noted above. The principal merits of the method are rapidity and simplicity.

In determining the specific gravity of cold pulp, this same apparatus may be used. Here, however, entrapped air becomes a very serious source

Table 32. Relation between Total Solids and Specific Gravity of Tomato Pulp and Filtrate

Per cent solids in pulp	Specific gravity at 20°C.		Per cent solids in pulp	Specific gravity at 20°C.		Per cent solids in pulp	Specific gravity at 20°C.	
	Pulp	Filtrate		Pulp	Filtrate		Pulp	Filtrate
3.42	1.0150	1.0133	7.06	1.0297	1.0274	10.41	1.0433	1.0404
3.53	1.0155	1.0138	7.17	1.0301	1.0279	10.52	1.0437	1.0409
3.64	1.0159	1.0142	7.28	1.0306	1.0283	10.64	1.0442	1.0413
3.76	1.0163	1.0146	7.34	1.0308	1.0285	10.70	1.0444	1.0415
3.87	1.0168	1.0151	7.45	1.0313	1.0290	10.80	1.0449	1.0419
3.98	1.0172	1.0155	7.56	1.0317	1.0294	10.91	1.0453	1.0424
4.09	1.0177	1.0160	7.62	1.0320	1.0296	10.97	1.0456	1.0426
4.20	1.0181	1.0164	7.74	1.0324	1.0300	11.08	1.0461	1.0430
4.26	1.0183	1.0166	7.85	1.0329	1.0305	11.20	1.0465	1.0435
4.37	1.0188	1.0170	7.90	1.0331	1.0307	11.25	1.0467	1.0437
4.48	1.0192	1.0175	8.02	1.0336	1.0311	11.36	1.0472	1.0441
4.59	1.0197	1.0179	8.12	1.0340	1.0315	11.47	1.0476	1.0446
4.71	1.0201	1.0183	8.24	1.0345	1.0320	11.59	1.0481	1.0450
4.82	1.0205	1.0188	8.35	1.0349	1.0324	11.70	1.0485	1.0454
4.93	1.0210	1.0192	8.46	1.0354	1.0328	11.81	1.0490	1.0459
5.03	1.0215	1.0196	8.57	1.0358	1.0333	11.93	1.0494	1.0463
5.10	1.0217	1.0198	8.68	1.0363	1.0337	12.05	1.0499	1.0467
5.21	1.0222	1.0203	8.74	1.0365	1.0339	12.10	1.0501	1.0469
5.33	1.0226	1.0207	8.86	1.0370	1.0344	12.21	1.0505	1.0474
5.44	1.0230	1.0211	8.96	1.0374	1.0348	12.32	1.0510	1.0478
5.55	1.0235	1.0216	9.14	1.0381	1.0354	12.43	1.0515	1.0482
5.66	1.0240	1.0220	9.25	1.0386	1.0359	12.55	1.0519	1.0487
5.77	1.0244	1.0225	9.36	1.0390	1.0363	12.65	1.0524	1.0491
5.88	1.0249	1.0229	9.47	1.0395	1.0368	12.77	1.0528	1.0495
5.94	1.0251	1.0231	9.58	1.0400	1.0372	12.88	1.0533	1.0500
6.05	1.0256	1.0235	9.70	1.0404	1.0376	12.99	1.0538	1.0504
6.16	1.0260	1.0240	9.80	1.0408	1.0381	13.10	1.0542	1.0508
6.22	1.0263	1.0242	9.92	1.0413	1.0385	13.22	1.0547	1.0513
6.33	1.0267	1.0246	10.02	1.0417	1.0389	13.32	1.0551	1.0517
6.45	1.0272	1.0251	10.14	1.0421	1.0394	13.44	1.0556	1.0521
6.50	1.0274	1.0253	10.25	1.0426	1.0398	13.55	1.0560	1.0525
6.61	1.0279	1.0257	10.35	1.0430	1.0402	13.66	1.0565	1.0529
6.72	1.0283	1.0261	.....	......	......	13.78	1.0569	1.0533
6.84	1.0288	1.0266	.....	......	......	13.89	1.0574	1.0537
6.95	1.0292	1.0270	.....	......	......	14.01	1.0579	1.0541

source: After Bigelow and Fitzgerald.

of errors, and the cup and contents must be centrifuged several minutes to expel air before the weighing is made.

Pycnometers. Special heavy-walled small bottles, or pycnometers, weighed on an analytical balance, are now used by many chemists in preference to the metal cup described above.

By Hydrometer. Because of the thick consistency of tomato pulp, it is difficult to obtain accurate hydrometer readings on the unfiltered pulp.

Bigelow and Fitzgerald found that the juice from the hot pulp may be quickly filtered through a cheesecloth to give a filtrate practically free from suspended solids. The specific gravity or Brix of the filtrate can then be determined with speed and accuracy. The temperature also is taken and suitable correction made, or the filtrate is chilled in the cylinder by packing it in crushed ice and the reading is taken at the standard temperature of 20°C. (68°F.). They have established the relation between the hydrometer reading so obtained, the specific gravity of the unfiltered pulp, and the total solids by drying to constant weight *in vacuo* at 70°C. (158°F.) as shown in Table 32. (Table 1 of *National Canners Association Bulletin* 27-L, revised 1950).

Canners report that the method gives good results in practice and is rapid and dependable, although it is recommended that the hydrometers used be checked each season against a standard method such as the pycnometer method. This is desirable because of the personal factor involved, the variation in hydrometers, variation in method of preparing pulp, and variation in the composition of the tomatoes themselves. Often a Brix instead of a specific-gravity hydrometer is used.

By Weight of Dried Sample. As indicated in Table 32 (Table 1 of *National Canners Association Bulletin* 27-L) there is a definite relation between specific gravity and total solids determined by drying at 70°C. *in vacuo.* When dried in an oven at atmospheric pressure, tomato products decompose rather rapidly and results for moisture so obtained will be too high.

The official method for this determination is as follows:

Place from 2 to 4 grams of the well-mixed sample in an accurately weighed flat-bottomed dish about 2½ in. in diameter, spreading thinly. Accurately weigh dish and sample. Place in a vacuum and dry at 70°C. and 28 to 29 in. vacuum (inches of mercury) for 4 hours. Remove and weigh immediately. [See "Official and Tentative Methods of Analysis" of the Association of Agricultural Chemists.]

In the absence of a vacuum oven 10 grams of the sample is evaporated to dryness in a broad shallow dish over a steam bath. It is then dried in an oven at 95 to 100°C. (203 to 212°F.) for 4 hr. and weighed. The per cent of solids thus obtained is multiplied by 1.085 to give the true percentage. This method is not so accurate as drying *in vacuo* but will serve for factory control.

By Refractometer. In recent years the methods previously described have been supplanted to a very great extent by the Abbe refractometer. This instrument consists of two prisms between which a few drops of the sample is placed; a mirror which reflects light upward through the prisms; a telescope with cross hairs; a scale reading in refractive index or in degrees Brix, or both; and a compensator to correct for chromatic dispersion of the light. The prisms are surrounded by water jackets through which water

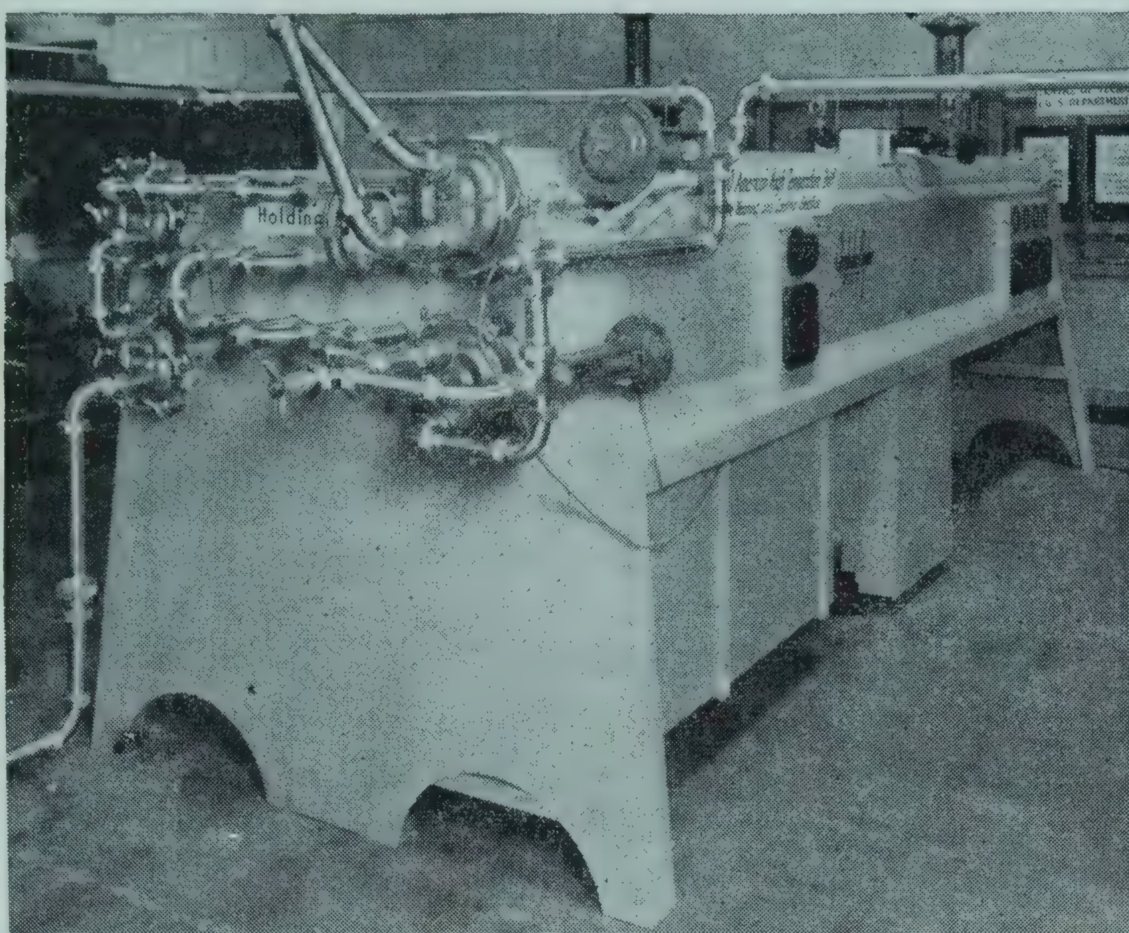


FIG. 78. High-temperature heat exchanger or flash pasteurizer. (*Chisholm Ryder Co. and Norton Advertising Service.*)

may be circulated to maintain a constant temperature, the usual standard temperature for this instrument being 20°C. (68°F.). If the temperature at which the reading is made is other than 20°C., add 0.0001 to the observed refractive index for each 1°C. above 20°C. or subtract the same quantity for each 1°C. below 20°C. With use it is occasionally necessary to adjust the instrument. Its "zero setting" is easily checked by determining the refractive index of distilled water; this at 20°C. is 1.3330. By allowing water from the cannery water main to flow through the jackets of the prism, they may be maintained at a fairly constant temperature (Figure 82).

In using the instrument for factory control, a sample of the hot product is taken from the kettle; a 10-cc. pipette is filled with the hot pulp, cooled under the water tap, and wiped free of water; the bottom portion is discarded; the prisms are closed; the tip of the pipette is placed against the funnel-shaped hole on the side of the prisms; and a drop or two of the

sample is allowed to flow in between the prisms. The liquid that flows into the orifice leaves behind much of its solid pulp, giving a reasonably clear layer between the prisms. Or more commonly, 25 or 30 cc. of the sample is poured into a small Erlenmeyer flask and cooled quickly under a water tap; a drop is removed by a spatula or rubber-tipped glass rod; it is placed on the open prism; the prisms are closed; and the reading is taken. Gurley (1946) states that the most common source of error is evaporation of water from the sample. Therefore it should be cooled quickly in a stoppered flask or bottle under a cold-water tap. A somewhat clearer reading is obtained if the cooled pulp is strained through a small piece of cheesecloth and a drop of the strained liquid is placed between the prisms. If cold water is circulating through the jackets of the prisms, the drop of sample quickly assumes the temperature of the instrument.

The prisms must be well cleaned with a soft cloth after each sample is read. As the glass of the prisms is very soft, great care must be taken to avoid scratching their surface.

For pulps containing up to 12 per cent total solids Bigelow and others (1934) give the following formula for calculating per cent solids of pulp from the refractive index:

$$\text{Per cent solids} = 4.00 + 691\,(n_D - 1.3382) + 1{,}029(n_D - 1.3382)^2$$

For pulps ranging from 12 to 20 per cent solids the formula becomes

$$4.54 + 644(n_D - 1.3382) + 959(n_D - 1.3382)^2$$

In these formulas n_D is the observed refractive index. Most refractometers used in canneries give soluble solids or Brix degree directly.

The relation between refractive index and total solids content is markedly affected by the concentration of added salt, sugar, and acetic acid. Accordingly it is customary in most cannery laboratories to construct a large graph on coordinate paper with refractive index as abscissas and per cent solids determined by vacuum oven as ordinates, or a table showing the same information is constructed. In either case the product of the plant in question is used. By making accurate determinations of refractive index and total solids by vacuum oven on samples representing low, medium, and high total solids, the graph can be constructed easily, as the relationship is practically a straight-line function; or a table can be constructed by extrapolation.

Readings can be made very rapidly, less than 1 min. being required for the actual reading, or less than 5 min. for cooling a sample of the hot pulp, mounting a drop between the prisms, and taking the reading. Manufacturers supply tables showing the relation between refractometer readings and total solids. See also *National Canners Association Bulletin* 27-L on tomato products.

The Abbe refractometer is made by all leading instrument manufacturers and is a commonly used instrument in sugar laboratories.

Finishing. Tomato purée should be smooth in texture and fine-grained. The pulping machine allows relatively large pieces of pulp and some fiber to pass through the screens, and cooking coagulates or granulates the pulp more or less. Therefore it is customary, before canning the purée, to pass it through a finisher to improve the texture.

A finisher consists of a horizontal cylinder or a vertical cone made of a fine sieve of bronze, stainless steel, or monel metal, inside of which are heavy bristle brushes that revolve rapidly, causing the fine pulp to pass through the screen and the pieces of skin, seeds, fiber, etc., to pass out the end of the machine. The holes in the finisher screen are commonly 0.033 in. in diameter.

Canning and Sterilizing. If for household use, the purée should be canned in No. 1 or No. 2 cans; if for sale to large users, it is canned in No. 10 or in 5-gal. cans. As a matter of fact, little purée is canned for home use; most of it is packed on order for manufacturers of soup or catsup or for use by hotels, restaurants, and institutions.

The No. 10 and smaller cans are usually filled by a rotary automatic filler at 170 to 185°F. and sealed hot, generally no exhaust being necessary. The filled small cans are sterilized a short time in agitating cookers at 212°F.

The 5-gal. cans are filled boiling or scalding hot (180°F. or above) and are sealed at once with a soldering steel and cap. Most packers do not process the filled cans but rely upon the temperature of the hot pulp for sterilization. The 5-gal. cans are made of very heavy tin plate and with care can be used several seasons, provided the cans are rinsed thoroughly with hot water after opening and are dried at once to prevent rusting. These cans, particularly filled cans, must be handled carefully to avoid development of leaks.

At one time 50-gal. barrels were used generally for pulp, sodium benzoate or distilled vinegar being used as preservatives; or the barrels were filled hot and sealed without addition of preservatives. This practice is now no longer followed because of the frequent growth of mold and bacteria in the barrels with consequent frequent and costly condemnation by pure food officials.

Lot Records. The canner should stack each lot of pulp separately and give it a number or other mark of identification in order that goods below standard may be segregated from the better grades. A complete record of each lot should be kept, the record to contain data on quality, treatment of raw material, specific gravity, microscopic examination, and notes on any deviations from the usual procedure. Records of this type are very valuable in locating causes of trouble in the plant.

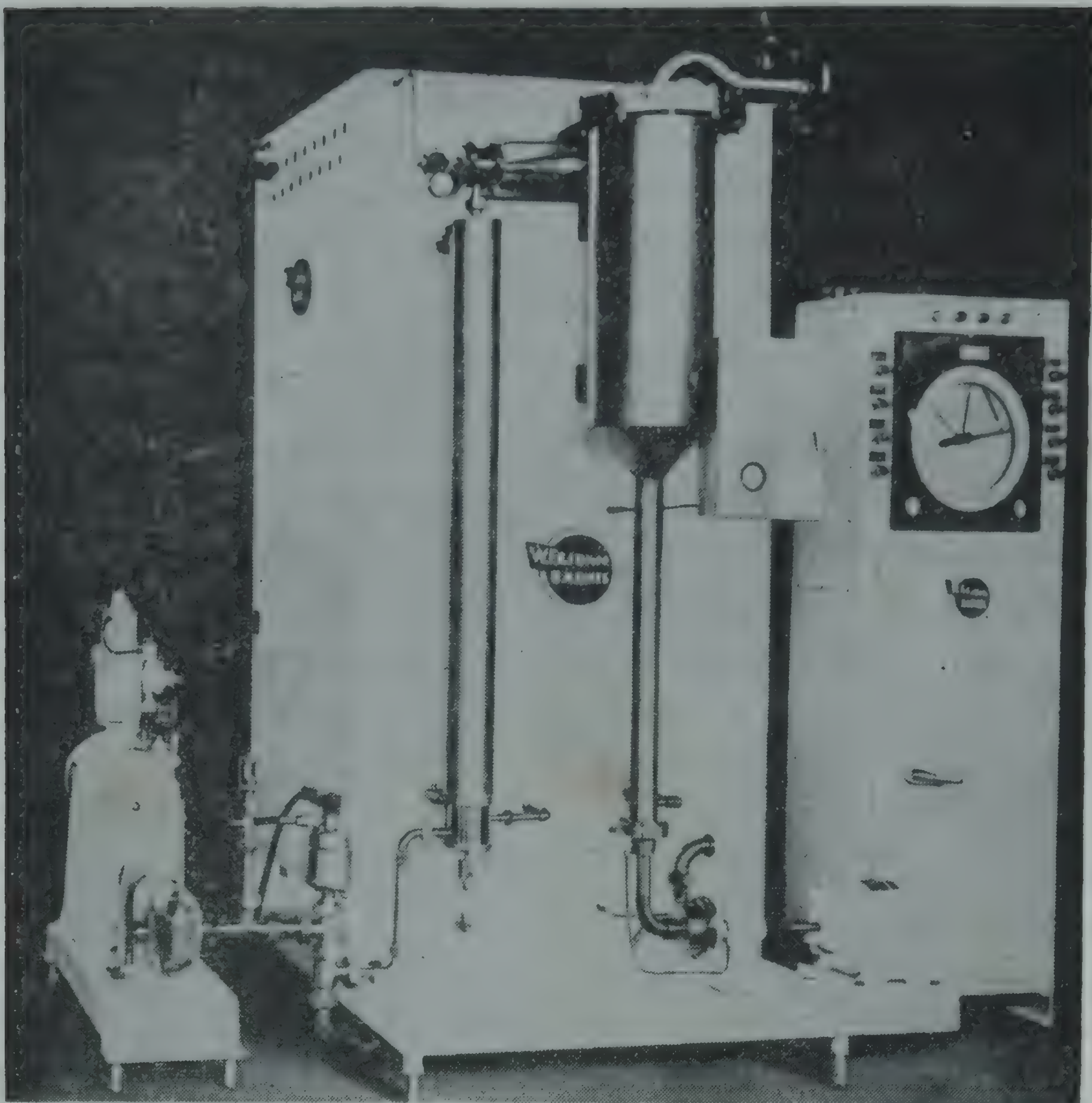


FIG. 79. Barnes heat interchanger for liquid food products. (*W. F. and John Barnes Co., Rockford, Ill.*)

Cooling. Tomato purée is a poor conductor of heat and, if stacked hot, is very apt to develop a brown color and scorched flavor through "stack burning." The cans should be promptly and thoroughly cooled with cold water (immersion or sprays) after processing.

Quality Control. Quality control is very important in the manufacture of tomato products. See later sections of this chapter for microscopical examination and an earlier section for total-solids determination. See also at the end of the chapter the section on laboratory control.

TOMATO PASTE

Tomato paste is a staple article of diet in Italy. It is a pasty, semisolid product of about the consistency of heavy apple butter. Present standards require that it contain at least 25 per cent total solids. Concentrated tomato paste must contain at least 33 per cent total solids. The usual tomato paste of commerce contains about 29 per cent of solids. Being highly concentrated, tomato paste is economical in its use of space and is not costly to transport.

A common procedure is about as follows: The tomatoes, often of the San Marzano variety, are washed; sorted; trimmed; crushed; heated to about 200°F. to extract pectin and inactivate enzymes; pulped; finished; concentrated in a single-, double-, or triple-effect vacuum concentrating unit and the resulting paste heated to 185 to 190°F. in a continuous pasteurizer; canned hot in 6-oz. cans; sealed; processed 2 to 4 min. at or near the boiling point; and cooled. A modification consists in canning at about 140 to 150°F., sealing, and processing for 15 min. at the boiling point of water.

In one form of batch-type pan the pulp is heated in a tubular heat interchanger outside the pan and sprayed into the vacuum chamber. It is recirculated until the desired density is reached. It gives a product of superior color and flavor.

Dried Tomato Products. Soups, paste, juice, cocktail, and other tomato products have been reduced to dry flakes or granules or powders by drum drying at atmospheric pressure or drying *in vacuo*. Sliced tomatoes have also been dehydrated (Chapter 19).

TOMATO CATSUP

As tomato catsup is the most popular condiment in the United States, a very large quantity of tomatoes is used in its manufacture.

Raw Materials. In some cases the catsup is made direct from the raw pulp; in others the pulp is produced, concentrated, and canned in various tomato districts and is shipped to large plants for conversion into finished catsup.

In any case, only clean wholesome tomatoes of intense red color and of meaty, not watery, texture should be used. High acidity and a rich tomato flavor are additional desirable qualities.

Preparation of the Pulp. The principles of preparing purée apply with equal or greater force to the preparation of pulp for catsup. Catsup is a more highly concentrated product than the average purée, and microorganism counts are thereby increased more or less proportionately, a factor that must be taken into consideration in selecting, sorting, washing, and otherwise preparing the pulp for catsup.

In most catsup plants in California the pulp for catsup preparation is made more or less as follows: The tomatoes must be of deep-red color; for that reason those that ripen late in the season are often too light in color for making a satisfactory catsup. At the plant an inspector of the State Board of Health and a member of the quality-control staff of the cannery inspect each load of tomatoes on arrival in order to determine whether the tomatoes are of acceptable quality. In general the requirements are similar to those for U.S. No. 1 quality as defined earlier in this chapter. The per cent of unfit tomatoes is determined by taking a generous sample from several

points in the load, carefully sorting and weighing the amounts of sound, satisfactory tomatoes and the culls. These latter include sunburned, worm-damaged, moldy, badly split, green, and "cat faces" or other unfit specimens. The canner sets a tolerance for per cent of culls, and if it should be exceeded, may reject the load and ask the grower to sort the tomatoes at his own expense. However, this happens rather rarely as growers are usually careful in picking the tomatoes and attempt to leave most of the unfit fruit in the field.

The boxes of tomatoes are usually carried by belt conveyer to the washing equipment, where they are dumped, usually by automatic box dumper in California, into a small tank of water.

From this small tank they are conveyed to the washing and sorting "belt," which is a conveyer made of stainless steel or bronze rollers carried by chain conveyer along supporting metal runways. As they move forward the rollers turn rapidly and cause the tomatoes also to turn over and over as they are conveyed. At the entry end of the conveyer very powerful sprays of water wash the tomatoes and usually cut away small sections of fruit that may have been softened by mold. Women standing at each side of the "belt" sort the tomatoes. Moldy and worm-damaged specimens are discarded. Often the largest tomatoes are placed on a belt that conveys them to the department in which whole or standard tomatoes are canned; and the smaller tomatoes are conveyed to the catsup department. Those that require it are trimmed.

They are next crushed or cut by machine. Heating to at least 190°F. in a continuous heat exchanger is advisable in order to inactivate pectic enzymes that would otherwise destroy pectin and thus damage the consistency of the catsup and to extract the pectin from the skins, seeds, and pulp so that the catsup has a better consistency. However, in some plants the tomatoes are not given this preliminary heating, but are pulped cold, i.e., in the raw condition.

The next step is pulping. This is done as previously described for making tomato purée. The pulped product is then passed through a finisher to give it a fine, smooth texture. It is concentrated in one of two manners. In some plants it is boiled in open tanks to about 1.060 specific gravity; in several other catsup factories in California it is concentrated in vacuum pans to this density. At this stage it is ready for the final cooking with the other catsup ingredients. The foregoing procedure is probably the one used in the majority of plants, although in some others the unconcentrated pulp is cooked with the spices, and the extraction of the spice flavors and the concentrating of the pulp are conducted simultaneously. If this method is followed, the spices may be held in cloth bags so that they may be easily removed at the end of the cook.

Addition of Flavoring Ingredients. Again speaking for the majority of the catsup plants in the West, the partially concentrated pulp of about

1.060 specific gravity is heated to boiling in open stainless-steel or glass-lined kettles and cooked a short time to the final desired total solids content with the required quantities of salt, sugar, vinegar, onion powder or chopped raw onions, and a mixture of certain spices. Garlic powder in small amount and paprika powder may also be included, the former for flavor and the latter for its deep-red color. The spices are now usually added in the form of a blend of dextrose sugar and the spice oils, or as an extract made by heating the whole spices in distilled vinegar for several hours at the simmering point, or as an acetic acid extract, or as the spice oils in a carrier such as an edible oil or vinegar. Another form is a highly concentrated extract known as a spice oleoresin. The extracts or the blend of dry sugar and spice oils, onion powder, garlic powder, cayenne, and any other dry ingredient, except the salt and sugar, may be measured or weighed in an amount sufficient for one kettle of catsup. The cook then merely adds the weighed or measured quantity when the batch of pulp has been concentrated to the customary density, whether it be a specific gravity of 1.058 to 1.060 or other point. The addition of the spices in a bag with the tomato pulp may be objectionable as they impart considerable amounts of tannin and dark color to the catsup. The tannin extracted from cloves and other spices may react with small amounts of iron extracted from equipment or the metal cap of the bottle, resulting in a dark, or even black, discoloration, especially in the neck of the bottle where oxidation of the iron may take place. Other advantages of the dry mixture of dextrose or sucrose and spice oils or vinegar extracts or acetic acid extracts is their convenience and greatly lessened danger of mistakes in the cookroom, such as forgetting to add the spices, or mistakes in weighing or measuring during the rush of cooking the catsup. The flavoring mix can be weighed or measured in advance into buckets or other medium-size containers, each containing enough of the mix for one kettle of catsup.

The spices and vinegar are added after preliminary concentration of the pulp or purée in order that volatile oils of the spices and the acetic acid of the vinegar will not be lost during concentration. For the sake of illustration it will be assumed that the purée has been concentrated to 1.060 specific gravity. The salt, sugar, vinegar, and the spice mix are then added in an open stainless-steel kettle which may contain, for illustration, 500 to 1,000 gal. of the purée. The batch is then boiled to the desired total solids content, as determined by examination of samples taken from the kettle, and placed in a refractometer. Different producers have their own formulas in respect to spicing and finishing, i.e., final total solids content. A common range, however, is from about 32 to 36 per cent total soluble-solids content in the final product.

Onions and garlic may be added in the chopped raw form or as the powdered dehydrated products. As the catsup is passed through a finisher after the final cook, any particles of onion, etc., are removed.

Salt and sugar should be sprinkled into the boiling purée and not added in bulk "by the bucketful," so that they will dissolve quickly and not sink to the bottom of the kettle to form large slowly dissolving lumps.

Distilled vinegar of 100-grain strength (10 per cent acetic acid content) is used in preference to cider vinegar because it is colorless, of high acetic acid content, and less costly and does not impart noticeable flavor. The acetic acid is the principal preservative of the catsup after the bottle is opened.

Determining the Finishing Point. The cooking process is continued until the desired consistency is obtained. The end point is determined, as previously mentioned, in most factories by refractive index. It is also customary to use a measured volume of purée and to condense this to a definite volume, which by experiment has been found to correspond to the final specific gravity desired; a refractive index or specific-gravity reading is then made (see paragraphs on determining the specific gravity and refractive index of purée). The Abbe refractometer is used in practically all catsup factories at present (Table 33).

The following table, after Bigelow, Smith, and Greenleaf (1950), gives the relation between total solids and the refractive index of tomato catsups of average commercial composition. There will be some deviation from these values according to the tomatoes and formula used. The proportions of salt, sugar, and acetic acid affect the relationship of refractive index and total solids markedly.

For the catsup formula given earlier, a final specific gravity of approximately 1.145 to 1.165 will give a catsup of satisfactory consistency. This density corresponds to about 32 to 36 per cent total solids, a large proportion of which consists of sugar and salt.

Finishing. Catsup should be smooth in consistency and free from large pieces of spices, onion, garlic, etc. Therefore, when the desired specific gravity has been reached, the hot catsup is passed through a finishing machine which removes coarse material and overcomes any tendency of the product to become "grainy."

The acetic acid of the catsup attacks some metals rather vigorously, and for this reason the finisher screen should be made of resistant metal, such as monel metal, bronze, or stainless steel.

Bottling. In some factories the hot finished catsup is run by gravity direct into bottles, which have been thoroughly washed previously and are scalded hot at the time of filling (Figure 66). In most plants the catsup is transferred from the finisher to a jacketed kettle above the filling machine, where it is heated nearly to the boiling point before being filled into bottles. A short direct pipe connects the heating vessel with the filling machine, so that very little cooling of the catsup occurs during transfer to the bottle. A steam-jacketed, stainless-steel pipe may also be used instead of a kettle to heat the catsup before filling.

TABLE 33. PER CENT TOTAL SOLIDS, SPECIFIC GRAVITY, AND ABBE REFRACTOMETER READING IN TOMATO CATSUP, AT 20°C. (68°F.)

Per cent total solids	Specific gravity	Refractive index at 20°C	Per cent total solids	Specific gravity	Refractive index at 20°C
16.0	1.067	1.3557	28.5	1.128	1.3767
16.5	1.069	1.3565	29.0	1.131	1.3775
17.0	1.072	1.3573	29.5	1.133	1.3784
17.5	1.074	1.3582	30.0	1.136	1.3793
18.0	1.077	1.3590	30.5	1.138	1.3802
18.5	1.079	1.3598	31.0	1.140	1.3811
19.0	1.082	1.3606	31.5	1.143	1.3820
19.5	1.084	1.3614	32.0	1.145	1.3829
20.0	1.087	1.3622	32.5	1.148	1.3838
20.5	1.089	1.3631	33.0	1.150	1.3847
21.0	1.091	1.3639	33.5	1.153	1.3856
21.5	1.094	1.3647	34.0	1.155	1.3865
22.0	1.096	1.3655	34.5	1.158	1.3874
22.5	1.099	1.3664	35.0	1.160	1.3883
23.0	1.101	1.3672	35.5	1.162	1.3893
23.5	1.104	1.3681	36.0	1.165	1.3902
24.0	1.106	1.3689	36.5	1.167	1.3911
24.5	1.109	1.3698	37.0	1.170	1.3920
25.0	1.111	1.3706	37.5	1.172	1.3930
25.5	1.113	1.3715	38.0	1.175	1.3939
26.0	1.116	1.3723	38.5	1.177	1.3949
26.5	1.118	1.3732	39.0	1.180	1.3958
27.0	1.121	1.3740	39.5	1.182	1.3968
27.5	1.123	1.3749	40.0	1.185	1.3978
28.0	1.126	1.3758			

SOURCE: After Bigelow, Smith, and Greenleaf.

Deaeration. A recent advance consists in deaerating the hot catsup by passage through a vacuum deaerator. This gives a more fluid product and protects color and flavor by removal of dissolved and occluded air. Deaeration is now standard practice.

Pasteurizing. If the catsup is heated to near the boiling point and is filled at 185°F. into hot sterilized bottles which are sealed immediately after filling, it is not necessary that the bottled catsup be sterilized or pasteurized. If, however, the temperature drops to 160°F. or less during the interval between finishing and bottling, it will be necessary, in most cases, to heat the catsup in the bottle in order to prevent spoilage.

A temperature of 180°F. for 45 min. is ordinarily considered a severe enough pasteurization for catsup filled at above 160°F. Catsup is a very

poor conductor of heat, and the manufacturer should make heat-penetration tests of his product in various sizes of bottles in order to adjust his pasteurizing time and temperature more intelligently.

Washing. If the catsup is not pasteurized, the filled and sealed bottles should be passed through a vat of hot water or beneath sprays of hot water to remove catsup adhering to the outside of the bottles; otherwise it will dry tightly to the bottles and be difficult to remove.

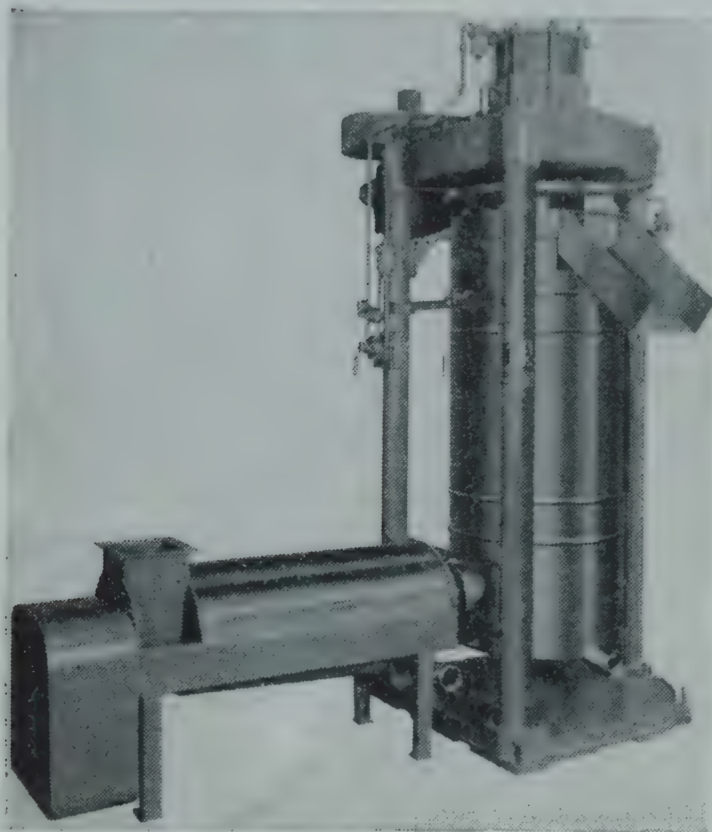


FIG. 80. Vertical screw press. (*Food Machinery Corp.*)

Canning. Some catsup is canned in No. 10 lacquered cans, and if filled at about 180°F., no sterilization is necessary.

Sodium Benzoate. At one time most catsup was preserved with $\frac{1}{10}$ per cent of sodium benzoate, and often its use was associated with catsup of extremely poor quality.

Sodium benzoate is not used at present in any of the leading brands of catsup. The present-day manufacturer depends upon the acetic acid of the vinegar and the preservative action of the spices to prevent spoiling after the bottle has been opened.

Spoilage. Catsup is subject to two types of spoilage or deterioration, viz., blackening near the surface and spoilage by microorganisms.

Blackening. Investigation has shown that the blackening is caused by the formation of iron tannate and that the presence of air appears to be essential for the reaction.

Iron is dissolved in the ferrous condition from equipment coming in contact with the purée or catsup during manufacture or is dissolved by the acetic acid of the catsup from the metal of the bottle cap. In the presence of air, which may be present in the bottle because of slack filling or which may have entered the bottle through a faulty cap, oxidation of the iron to the ferric state takes place. The ferric salts combine with tannin, extracted from the spices or from the stems and seeds of the tomatoes, to form a black, finely divided precipitate of iron tannate. The heads of cloves have been found to be rich in tannin; hence the advice to use headless cloves. Deaeration of the hot catsup as previously described greatly reduces the danger of darkening.

Caps should be lined with cork disks, and these in turn faced with lac-

quered paper spots in order to preclude any possibility of the catsup coming in contact with the metal of the cap.

Spoilage by Microorganisms. Carl S. Pederson and associates of the New York Agricultural Experiment Station and S. H. Ayers and associates of the Glass Container Association have conducted much research on the spoilage of tomato catsup by bacteria and yeasts.

Pederson found that most of the spoilage of bottled catsup in New York state was caused by non-spore-forming organisms belonging to six species of Gram-positive, lactic acid–forming organisms of the *Lactobacillus* and *Leuconostoc* genera. Five species formed gas abundantly in catsup and in sugar-containing media; one formed acid, but not gas. None of the organisms are very heat-resistant; all were killed at 170°F. in a very few minutes.

Ayers found yeast in many fermenting bottles of catsup. He concluded that in filling bottles with hot catsup the catsup in the neck may cool so quickly that organisms there may not be killed. Pasteurization after bottling is the remedy.

In California plants, spoilage of catsup has not been serious. The high acetic acid content of catsup renders it easily sterilized by heat and resistant to spoilage by microorganisms after the bottle is opened. On this account the addition of a preservative such as sodium benzoate is not necessary. However, when opened bottles of catsup stand on a restaurant table for many weeks, filled from time to time from a can of catsup, acid-resistant yeasts, molds, and bacteria may become established and partially spoil the product.

Antiseptic Action of Spices and Condiments. It has been shown by K. G. Bitting that curry, ginger, mace, paprika, peppers, and sage possess little or no antiseptic value in preventing the growth of mold or yeast. Allspice, cinnamon, and cloves exhibit some antiseptic action on these organisms.

The active ingredients of these spices are the oils extracted or added in the process of manufacture. Eugenol from the oils of allspice and cloves and cinnamic aldehyde from oil of cinnamon are stated to be the active ingredients. According to Mrs. Bitting these are present in very small concentrations in catsup, e.g., approximately 1:138,000 and 1:259,000, and therefore exert very little antispetic action. Hier states that 1.25 per cent acetic acid will preserve catsup at least 2 weeks under normal conditions, long enough to permit the catsup to be consumed on the average table after the bottle has been opened. Acetic acid appears to be the most active preservative in catsup and in this respect is probably much more important than the spices. The usual acetic acid content of catsup is 1.50 per cent or above.

The amount of sugar used in catsup is not sufficient to exercise any

appreciable antiseptic effect; its principal purpose is to counteract the acid taste of the acetic acid.

Formulas. As previously mentioned, each producer follows a procedure and formula best suited to his operating conditions and the preference of his trade. Usually the formula is a trade secret. The following formula was used at one time by a California plant of medium capacity. Whole spices were used.

Purée of 1.060 specific gravity	100 gal.
Salt	28 lb.
Sugar	125 lb.
Chopped onions	25 lb.
Chopped garlic	8–16 oz.
Cinnamon, broken bark	25 oz.
Mace	3½ oz.
Cloves, whole headless	15 oz.
Allspice	15 oz.
Cayenne, powdered	3½ oz.
Paprika, powdered, optional	2 lb.
Vinegar, 100-grain distilled	12 gal.

The spices (except paprika, onions, and garlic) are placed in the vinegar and cooked in a covered kettle about 2 hr. at the simmering point, and the sugar and salt may then be dissolved in the vinegar. The extract thus obtained, freed of the solid spices, is added to the catsup near the end of the boiling process. The paprika is added in powdered form directly to the catsup, if the manufacturer desires to use it. The above formula makes slightly more than 100 gal. of catsup.

If desired, the spices may be boiled in a bag with the purée, the chopped onions and garlic being added direct to the tomato pulp. They can be separated from the catsup, after cooking, by means of a finisher. The whole spices may be replaced with spice oils or other spice concentrates.

CHILI SAUCE

Chili sauce is made from peeled whole tomatoes and is not pulped or passed through a finisher at any stage of manufacture. It is used as a flavoring in cooking and to some extent as a table relish.

Preparation of the Tomatoes. The tomatoes are peeled and cored as for canning.

Flavoring. Spices, onions, garlic, sugar, vinegar, and salt are used in much the same manner as in making catsup. In some plants the spices, onions, and garlic are added to vinegar and an extract made as described for catsup. In others spice extracts or other spice concentrates are used as previously described for catsup. In some cases the raw onions and garlic or

their dried powders are added directly to the tomatoes and left in the final product.

One formula is as follows:

Whole peeled tomatoes	840 lb.
Chopped onions	35 lb.
Whole allspice	½ lb.
Whole cloves, headless	⅔ lb.
Cinnamon, stick	2½ oz.
Mustard	⅔ lb.
Garlic, ground	½ lb.
Distilled vinegar (of 10 per cent acetic acid)	5 gal.
Salt	14 lb.
Sugar	60 lb.

The spices, except the cayenne and mustard, are heated in a covered vessel to the simmering point in the vinegar for about 2 hr. and then strained. The peeled tomatoes are concentrated, preferably in a vacuum pan or stainless-steel or glass-lined kettle, to about one-half their original volume with part (about one-third) of the sugar. The spiced vinegar, powdered cayenne, powdered mustard, salt, and the remainder of the sugar are added near the end of the boiling process. A dry mixture of spice oils and dextrose is often used. The salt must be added slowly in order to make certain that it will dissolve, or it may, if desired, be dissolved in the vinegar.

Spices can be extracted in a cloth bag in the boiling tomatoes as described for catsup or may be added in the form of oils or oleoresins.

The cooking is conducted in the same manner as for catsup and for the same purposes, viz., to concentrate the tomatoes and to blend the tomatoes and flavoring materials.

End Point. The end point is determined by appearance, although the tomatoes are usually weighed and concentrated to a definite volume as with catsup. The end point is now generally determined by refractometer.

Bottling. Widemouthed bottles are used because of the large pieces of tomatoes present in the sauce. An automatic rotary filler is used, and the bottles are sealed with special caps in an automatic sealer. If they are filled at or above 185°F., sterilization is not necessary; otherwise the bottles are pasteurized at 180 to 200°F. as described for catsup.

HOT SAUCE

An important amount of tomatoes is used in hot sauce, a lightly spiced purée of hot flavor sold in small cans for flavoring in cooking. It can be prepared cheaply and frequently has sold retail for 5 cents per 8-oz. can; at present (1957) for 5 to 7 cents. Numerous formulas are in use, in which cayenne is the predominating flavoring. The following formula is typical.

To 700 gal. of raw pulp add the following ingredients finely ground:

	Lb.
Green chili peppers	100
Onions, fresh or equivalent dehydrated	75
Garlic, fresh or equivalent dehydrated	2½

Concentrate to about 425 gal. and add:

	Lb.
Ground cayenne pepper	2½
Salt	70

Stir thoroughly or boil a short time to dissolve salt and to mix the cayenne; pass through a finisher to remove chopped flavoring materials, can boiling hot, and seal at once in 8-oz. cans.

In some cases the garlic is omitted and the proportions of other ingredients are reduced in order to produce a sauce of milder flavor.

The tomatoes are washed, sorted, trimmed, and pulped as in making purée, paste, or catsup. The expense of hand peeling is therefore avoided. Pulp from trimmings, peels, and cores is also used in making hot sauce.

TOMATO JUICE

The pack of canned and bottled tomato juice has grown from practically nothing in 1928 and 165,251 cases in 1929 to 38,017,000 cases in 1956, according to *Western Canner and Packer*. It is used principally as a breakfast drink, although suitable for use in many other ways. Most of the pack is canned, relatively little being packed in glass. California, New York, Indiana, and Maryland are heavy producers of this juice.

It is unflavored except for the addition of a small amount, about 0.60 per cent or less, of salt.

Food Value. When tomato juice is properly made and preserved, it contains about half as much vitamin C and several times as much vitamin A as orange juice. Like orange juice it contains considerable basic ash, and on digestion leaves an alkaline residue. It is a good source of Fe, Mn, and Cu.

Definition. The Federal food and drug regulations define tomato juice as "the unconcentrated, pasteurized product consisting of the liquid with a substantial portion of the pulp, expressed from ripe tomatoes with or without the application of heat and with or without the addition of salt." This definition excludes filtered juice, since it does not contain pulp.

Varieties. Tomatoes to be used for juice should possess high color, rich flavor, and high total acidity. They should be juicy rather than mealy in texture. The Stone is a very good juice variety; the Pearson and Norton are the principal varieties used in California for juice. See also the section

on purée for additional varieties. Overripeness results in a juice of poor flavor, and underripeness in one of poor color and flavor.

Preparation for Pressing. Great care must be taken in sorting, trimming, and washing tomatoes for juice production. These operations are conducted as previously described for preparing tomatoes for purée and catsup.

Retaining Vitamin C. One of the most difficult problems is to prevent loss of vitamin C through oxidation. According to data reported by Kohman (1931), practically all this vitamin may be lost if the juice is heavily aerated during extraction of unheated tomatoes; presumably vitamin C is oxidized by the dissolved oxygen. He found that heating the tomatoes to boiling before extraction prevented loss of vitamin C. He also found that it is retained if the juice after extraction is immediately subjected to a high vacuum. One large California packer at one time used this procedure very successfully. If vacuumizing is omitted, it would then appear that the tomatoes should be heated sufficiently before expressing the juice. One procedure that has much to commend it as a means of protecting vitamin C calls for coarsely slicing the tomatoes, heating to 180 to 190°F., out of contact with air, in a steam-jacketed heater, and pulping scalding hot. See a later paragraph on preheating, also Figures 73 and 78.

Cameron et al. (1955) have reported on vitamin retention in juices made in three canneries using different methods of preparation. In cannery A the tomatoes were steamed at 190°F. for 1 min., crushed, extracted on a vibrating screen, passed through a finisher; the juice was deaerated, flash-pasteurized at 250°F. and filled hot into cans. The cans were sealed, inverted, and allowed to air-cool. Retention of vitamin C in the final canned product was 94 per cent.

In cannery B the tomatoes were crushed, pumped at once through a heat interchanger in which they were heated to 185°F., then through a cyclone pulper and a finisher; the juice was heated in a tank to 190°F., salted, canned hot, sealed, and processed in the cans. Retention of vitamin C was 77 per cent, or considerably less than in cannery A.

In cannery C the tomatoes were steamed, chopped, and heated by copper coils to 195°F. The pulpy tomatoes were then pumped through a series of tanks in which they were successively heated by copper coils, screened, held, and the juice salted. The juice was canned and processed in a retort. The approximate time between extraction and canning was about 45 min. Retention of vitamin C was only 32 per cent.

The authors point out that small amounts of dissolved copper greatly accelerate loss of vitamin C. They also state that tomatoes do not contain an enzyme capable of catalyzing the oxidation of vitamin C and therefore that loss by oxidation is not enzymic. As the temperature of the juice or the crushed tomatoes is increased, the rate of oxidation of ascorbic acid increases to a certain temperature, and as the temperature is increased

further, the rate rapidly decreases, becoming practically zero at the boiling point. The critical temperature, the authors state, is probably between 160 and 180°F.

They found that the retention of other vitamins by the juice was very good. The juice is lower than tomatoes in carotene (vitamin A precursor), since it resides in the insoluble solid fraction and the juice does not contain all of the H_2O-insoluble fraction.

It is recommended that tomato-juice canners take all reasonable precautions to retain vitamin C because the value of the product as a food depends largely on its C content. Particularly is this true if it is to be used as a food for infants. The vitamin C content of the canned product should be determined regularly during the season. This can be done quickly by the iodine-titration–vitamin C assay or by titration with standard 2,6-dichlorophenol indophenol.

Vitamin A. Vitamin A resides in the solid pulp and is insoluble in the liquid portion of the juice; therefore a reasonable proportion of the solid pulp should be included. Vitamin A is stable to heat and is not affected by the oxidation normally occurring in tomato-juice production. Vitamin B also appears to be rather stable under normal conditions of tomato-juice production.

Preheating. It is customary in most tomato-juice plants in California to heat the tomatoes before they are pressed for juice recovery. After very thorough washing under sprays of water at very great pressure the tomatoes are coarsely ground or crushed and are then pumped through a tubular, stainless-steel heat interchanger in which the tomatoes are heated for the purposes of improving extraction of the juice and inactivating or greatly reducing the activity of pectic enzymes. If these enzymes are not inactivated and there is a considerable delay between juice extraction and canning, pectin may be demethoxylated, with the result that the canned juice may show clotting or separation after the contents of the can are poured into a glass for serving. A temperature of 140°F. sometimes used in preheating the crushed tomatoes has been reported to not greatly reduce the activity of the pectic enzymes but that 160°F. materially retards subsequent activity and 180°F. practically eliminates it. Two California plants heat the crushed tomatoes to 190°F. or higher in the continuous-heat interchanger. Other things being equal, this would appear to be good practice (Figures 78 and 79).

Preheating also tends to protect vitamin C against undue loss through oxidation. It also improves the consistency of the juice by extracting pectin from the skins and seeds, and if high enough in temperature, by inactivating pectic enzyme action or greatly retarding it.

Expressing the Juice. In the early years of the industry much of the juice was prepared by passing the raw tomatoes through a cyclone (pulper), a procedure, according to Kohman, that destroys practically all of vitamin C.

Special machines have been developed for the purpose and are now in general use. One common form consists of a tapered screw revolving within a cylinder of perforated metal with holes 20/1,000 in. in diameter and 625 holes per square inch. The pressure applied can be varied to attain the degree of extraction desired. Light pressing, according to some canners, gives a juice of better flavor than does heavy pressing.

In one large Western plant the crushed tomatoes after heating to 190°F. are passed through a tomato pulper and then through a finisher. A very high yield of juice is obtained.

The juice extractor and other metal equipment should be made of metal that does not affect the vitamin C or the flavor and color of the juice; iron and copper particularly should be avoided. Pratt recommends stainless steel, monel metal, nickel, aluminum, and glass-lined steel.

Addition of Salt. Tomato juice contains about 0.5 per cent salt. Formerly it was customary to add it to the juice in a tank equipped with an agitating or stirring device. Then it was canned and processed.

Present practice usually consists in adding a measured volume of salt to each can of juice from an automatic salt dispenser as the can is conveyed from the filling machine to the can double seamer; or a small pellet of salt is added to the empty or the filled can by dispenser (Figure 43).

Homogenizing. At one time much tomato juice was homogenized before canning; i.e., it was pumped under very heavy pressure through a small orifice in order to induce a finely divided condition. Homogenizing imparts a thick consistency to the juice. If the normal amount of solid pulp is present, the juice after homogenizing is altogether too thick for use as a beverage; and if only enough pulp is left to give a homogenized juice of desirable consistency, it then is apt to be deficient in vitamin A. Homogenization unduly aerates the juice and, according to Pratt, injures the flavor. It has been discontinued in Western plants.

Processing and Canning. In the early years of the industry tomato juice was usually processed in the can at 212°F. or 218 to 220°F., in either case in a continuous agitating processor (sterilizer) of the types used for processing canned fruits at 210 to 212°F. or vegetables under pressure above 212°F. In recent years this procedure has been replaced in most juice plants with flash sterilization in a closed system in a heat interchanger at 240 to 250°F., followed by cooling to about 210°F., releasing to atmospheric pressure, and canning at 205°F. or higher. This change in procedure was made advisable because of serious spoilage in canneries east of the Rockies by a heat-resistant flat-sour thermophile, *Bacillus thermoacidurans*, and in the West by a heat-resistant, acid-tolerant organism, *Clostridium pasteurianum*. It was difficult to kill the spores of these bacteria in the canned product by heating without damaging the color and flavor of the juice by the long period of heating found necessary.

At 240 to 250°F., fortunately, the increased temperature has a much

greater killing action on the spores relatively than its damaging effect on quality of the juice. In one plant the juice is heated in a three-stage FMC heat interchanger to 240°F. in about 15 sec., is held at that temperature for 45 sec., and then cooled in the third section to 210°F. The cans are filled at 203 to 206°F., closed at once, carried for 3 min. on a conveyer to sterilize the can and ends, and then spin-cooled under sprays of water. In another plant the juice is heated to 250°F. and held for 5 sec. at that temperature, then cooled to 205 to 210°F., filled at about 205°F., closed, conveyed in the open air for about 5 min., and then cooled in running cold water to 105°F. In another plant the juice is canned at about 180°F., and the cans are sterilized in a continuous agitating pressure retort at 218°F. for 18 min., and then cooled in running water.

Use of Press Cake. The press cake, consisting of skins, seeds, and considerable flesh, still contains considerable juice or pulp and can be cycloned to yield an inferior pulp suitable for use in canning with standard-pack tomatoes or in making second-quality catsup or other products. Catsup and other products so made are apt to be considered by-products. By use of the press shown in Figure 80, much additional juice can be obtained.

Quality Standards for Tomato Products. Earlier in this chapter, in the section on definitions, the general requirements of the food and drug regulations for several different tomato products were given. In addition, the U.S.D.A., Agricultural Marketing Administration, Processed Fruit and Vegetable Products Inspection, has established quality standards for various tomato products.

U.S. Grade A, or Fancy, canned tomato purée (tomato pulp) must possess a good red ripe tomato color and must be practically free from defects. It must possess a typical canned tomato purée (tomato-pulp) flavor and score not less than 85 points by the following scoring method:

	Points
Color	60
Absence of defects	40

The color is determined by comparing the sample with that produced by spinning a combination of the following Munsel color disks:

Disk 1	Red (5Rs. $6/13$)—(Glossy finish)
Disk 2	Yellow (2.5YR $5/12$)—(Glossy finish)
Disk 3	Black (N1)—(Glossy finish)
Disk 4	Gray (N4)—(Mat finish)

The color contains as much or more red color than that obtained by spinning the disks in the following combinations: 65 per cent of the area of disk 1, 21 per cent of the area of disk 2, and 14 per cent of the area of disk 3 or 4 or any combination of the two. For Grade A purée, color may score from 51 to 60 points.

Grade C, or Standard, tomato purée possesses a fairly good red tomato color and is fairly free from defects. It possesses a typical canned-tomato purée flavor and scores not less than 70 points by the foregoing scoring system.

Grade D, or Substandard, tomato purée is that which fails to meet the requirements of Grade C tomato purée (tomato pulp).

Additional instructions are given in the mimeographed circular of the U.S.D.A. on tomato purée quality standards.

For U.S. Grade A, or U.S. Fancy, tomato catsup the requirements are good color, good consistency, practically free of defects, good flavor, good finish, a total solids content of at least 33 per cent; a score of not less than 85 points in accordance with the scoring system established by the U.S.D.A.

For U.S. Grade B, or Extra Standard, the requirements are good color, good consistency, practically free of defects, good flavor, good finish, total solids content of at least 29 per cent; a score of not less than 85 points. The catsup should score not less than 18 points on consistency.

For U.S. Grade C, or U.S. Standard, the requirements are in most cases qualified by the word "fairly," as "fairly good color," etc. The total solids content is not less than 25 per cent. It scores at least 70 points.

Substandard catsup is that which fails to meet the requirements for grade C, U.S. Standard.

The scoring system for catsup is as follows:

	Points
Color	25
Consistency	25
Absence of defects	25
Flavor	25

Detailed specifications for Munsell color requirements and for procedures for arriving at scores for other factors are given in the mimeographed circular of the U.S.D.A., Agricultural Marketing Administration, obtainable on application to the agency.

U.S. Grade A (Fancy) tomato juice possesses the typical color of well-ripened tomatoes and good consistency; is practically free of defects; possesses the flavor of well-ripened tomatoes; and scores not less than 85 points according to the system outlined below.

U.S. Grade C (Standard) tomato juice possesses a fair tomato color and fair consistency; is reasonably free from defects; possesses a fairly good tomato flavor; and scores not less than 70 points by the following system.

Off Grade (Substandard) tomato juice does not meet the requirements for the foregoing grades; or one of the factors falls in the subdivision D; or falls below any standard promulgated under the terms of Section 8, Paragraph 5, of the Food and Drugs Act as amended.

The scoring system for tomato juice is as follows:

	Points
Color	30
Consistency	15
Absence of defects	15
Flavor	40
Total	100

Similar mimeographed circulars have been prepared for tomato sauce and tomato paste and are obtainable on application to the U.S.D.A., Agricultural Marketing Administration.

THE MICROSCOPICAL EXAMINATION OF TOMATO PRODUCTS AND CHEMICAL CONTROL

If moldy, soured, or fermented tomatoes are used in the manufacture of tomato products, microscopical examination will reveal the presence of excessive numbers of the organisms responsible for the decay. B. J. Howard has made an exhaustive study of this subject, and upon the results of his investigations the U.S.D.A. has established limits for the number of molds, yeasts, and bacteria that may be permitted in tomato products.

Howard Method

This method was first published in *U.S. Department of Agriculture, Bureau of Chemistry, Circular* 68 and was published a second time in 1917 in *U.S. Department of Agriculture Bulletin* 581. It has been adopted as a tentative method by the Association of Official Agricultural Chemists.

Standards for Microorganisms in Tomato Products. The Food and Drug Administration, U.S.D.A., and the various state boards of health consider tomato products unfit for food and subject to seizure and condemnation:

1. If mold filaments as determined by the Howard method are present in catsup, chili sauce, purée, and paste in more than 40 per cent of the fields examined by microscope. For juice the limit is 20 per cent.

2. If yeasts and spores are present in excess of 125 per $\frac{1}{60}$ cu. mm. as determined by the Howard method. This count is now seldom made.

3. If bacteria in excess of 100 million per cubic centimeter as determined by the Howard method are present. Bacterial counts are now seldom made.

Howard recommends a limit of 25 per cent for molds. By careful sorting and by the use of sound material, the commercial production of tomato products well below this suggested limit is perfectly feasible. The present standard of 40 per cent is liberal.

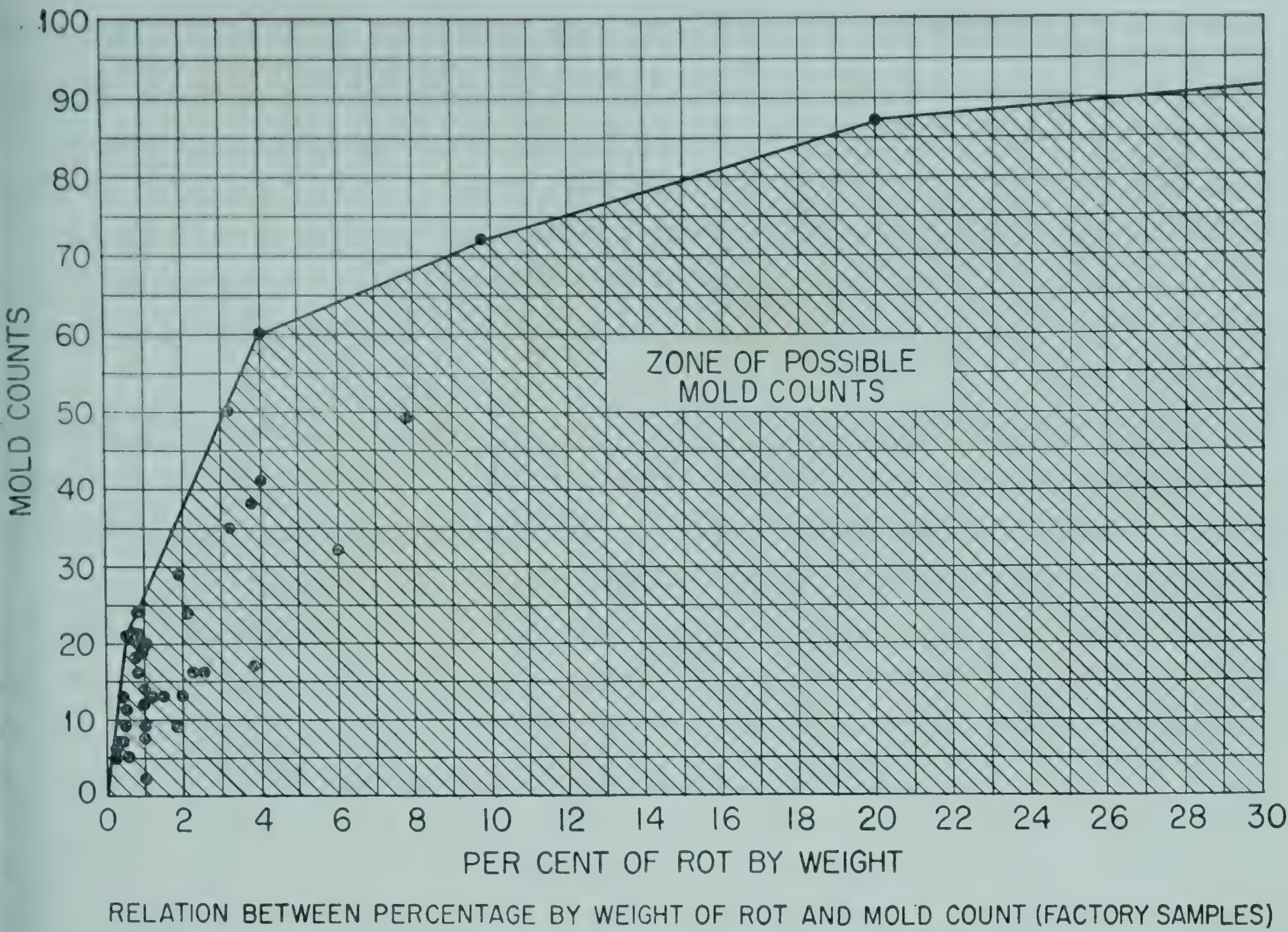


FIG. 81. Relationship between percentage of rot in fresh tomatoes and mold count in pulp. (*After Howard.*)

Interpretation of Results. The presence of large numbers of mold filaments indicates the use of unfit moldy raw material or contamination of the pulp by unclean, moldy equipment. It usually indicates the former condition and calls for more careful picking in the fields and more rigid sorting and trimming.

The presence of an excessive number of yeasts, spores, and bacteria usually indicates fermentation during a delay in the process of manufacture, although if the fruit is stored too long before pulping, fermentation and growth of these microorganisms may occur in cracked or crushed tomatoes before pulping.

Since the mold count is so much more important than the estimation of spores, yeasts, and bacteria, it is the determination most frequently made by pure food officials and prospective purchasers of large quantities of tomato products.

Relation of Percentage of Rot to Mold Count. It has been determined by Howard that there is a fairly definite relation between the percentage of rot by weight and the mold count. Numerous determinations were made of the percentage of rot in 25- and 60-lb. samples of the tomatoes from the sorting and trimming belts in a number of factories and of the per cent of fields of the finished pulp containing mold. The results of these determinations are shown graphically in Figure 81.

None of the samples containing less than 1 per cent by weight of rot gave excessively high mold counts. While the results show that a low count may not always indicate the use of sound raw material, they clearly demonstrate that a high mold count always indicates the use of unfit material (provided the molds have not come from unclean equipment). Any weakness in this method of determining the quality of the product favors the manufacturer and may occasionally permit passing of inspection by products that should be condemned.

In the figure, percentage of rot above 20 per cent is plotted as if 100 per cent would give a count of 100 per cent of fields showing mold. As a matter of fact, a count of 100 per cent will often be obtained with pulp made from tomatoes containing less than 20 per cent of rot by weight.

From the chart it is possible to estimate the minimum per cent by weight of rot in the raw material. Thus a mold count of 40 enters the "zone of possible mold counts" at a point representing 2.2 per cent of rot by weight. A count of 40, therefore, may represent from 2.2 to 100 per cent by weight of rot in the raw material but not less than 2.2 per cent.

Relation of Per Cent of Rot to Bacteria, Yeast, and Spore Counts. Counts of less than 15 million bacteria per cubic centimeter indicate little as regards per cent of rot in the original material, but above this point, according to Howard, each 1 per cent increase in weight of rot gives an increase of about 20 million bacteria per cubic centimeter. This relation holds to about 20 per cent by weight of rot. A low bacterial count does not always indicate the use of sound material.

The same general relations exist for yeasts and spores as for bacteria.

Effect of Peeling on Counts of Microorganisms. Chili sauce and canned tomatoes are prepared from peeled and well-trimmed stock in most cases, and as a consequence extremely low counts of molds, yeasts, and bacteria are the rule for such products. Similarly, coring the unpeeled tomatoes used for pulp, catsup, juice, etc., greatly reduces the mold count.

Effect of Method of Storage of Pulp. In former years it was customary to store tomato pulp (to be used for catsup, etc.) in wooden barrels with distilled vinegar or sodium benzoate as a preservative. Almost invariably such pulp has shown, on microscopical examination after several months' storage, very high counts of bacteria and often high mold counts.

Because of the frequent condemnation of barrel stock by food officials, this method of storage has practically gone out of existence and has been replaced by sterilization in 5-gal. or No. 10 cans.

Effect of Concentration. In highly concentrated tomato products, such as tomato paste, the increase in numbers of mold filaments is not strictly proportional to the degree of concentration. Thus if tomato pulp is concentrated 5:1, the molds will not increase in a similar ratio but will show a considerably smaller increase, probably because of breaking up of the

filaments and shriveling of the mold filaments by osmosis to such an extent that they are no longer recognizable under the microscope as molds.

This condition exists to a more limited extent with other concentrated tomato products, such as catsup, highly concentrated purée, etc., although it is most pronounced in tomato paste. For this reason food officials have experienced difficulty in establishing standards for tomato paste.

Accuracy of the Howard Method. Some food chemists and manufacturers of tomato products are inclined to doubt the value of the Howard method as a means of detecting spoilage or the use of unfit raw material. It has been proved many times, however, that the method in the hands of experienced analysts gives strictly comparable results and that it is possible to obtain results upon the same sample that agree closely. It has also been shown that any error in the method is more liable to favor the manufacturer than the food official. Its principal weakness lies in the fact that it does not always give a high count with products known to have been prepared from tomatoes containing an excessive amount of rot.

Howard Method for "Worm Count." In 1934 and 1935 infestation of tomatoes with the corn-ear worm and to a lesser degree with the larvae of the potato-tuber moth was heavy in certain Western states. Dr. B. J. Howard of the Federal Food and Drug Administration made an investigation in canneries and in the fields of the extent and character of the infestation and the methods of handling the tomatoes to remove the insects. He devised a method of detecting the worm fragments in the finished product.

Tomato fruits become infested by young worms hatching from eggs laid on the plant by adult females. The young worms feed to a slight extent on the leaves but usually crawl under the calyx of a tomato and burrow downward into the core. They carry on their feeding operations there and increase rapidly in size as well as in destructive action. The worm may develop to maturity in the core of the tomato or may move about from one tomato to another, cutting small feeding holes around the calyx or on the sides of the fruit. Microorganisms often gain entrance through the worm holes and cause decay. A tomato in which the worm develops to maturity becomes a mass of worm excreta, disgusting in appearance and wholly unfit for use in a food product.

It is difficult to control the worms by use of arsenicals or other poisonous sprays because of contamination of the fruit with the poison, making its use in the fresh state or unpeeled condition for tomato products dangerous. However, the problem of control in the fields is receiving intensive study. Much can be done by pickers in discarding evidently infested fruit in the fields. California tomato growers dust the vines with powdered calcium arsenate and find it effective; it can be removed from the fruit at the plant by proper washing. DDT has proved very effective and is in use commercially.

Often the presence of the worm in the core is not evident from the out side appearance of the fruit, and on this account some canners have core tomatoes used for juice. Incidentally, coring greatly reduces the mol count, since mold is frequently found in the stem cavity. However, th cost makes coring more or less impracticable.

Howard has adapted to the estimation of worm fragments in tomat products the method of J. D. Wildman, developed for recovery of small insects from certain other food products. The method is fully described in "Official and Tentative Methods of Analysis," Association of Official Agricultural Chemists, in *National Canners Association, Bulletin* 27-L, and by Howard in *U.S. Department of Agriculture Bulletin* 581.

FIG. 82. Abbe refractometer, 3L type, used for measuring soluble-solids content of tomato products, juice, sirups, and other products. (*Bausch and Lomb Optical Co.*)

The present tolerance established by the Federal Food and Drug Administration is a maximum of 30 fragments per 200 cc. for catsup and 10 per 200 cc. for juice. For purée the maximum fragment counts are 20 for 200 cc. of purée of 1.035 specific gravity; 25 for 1.043; 30 for 1.051; and 40 for paste of 1.071. The maximum for pastes of higher density is 50 fragments per 200 cc.

Fragments of certain spices may be mistaken for worm-skin fragments. As suggested by Howard, the analyst should thoroughly familiarize himself with the microscopic appearance of worm fragments prepared by grinding larvae of the corn-ear worm and other larvae involved (such as potato tuber moth larvae and pinworms). In addition, he should receive personal instruction from a state, Federal, or other microscopist engaged in this work.

Vinegar Fly (Drosophila) Eggs. As mentioned earlier in this chapter, vinegar flies have become a serious pest in the tomato fields in Western states. Unless controlled, they may lay eggs in large numbers on the tomatoes in the lug boxes and many of the eggs may be carried through into the tomato products. Therefore it has become necessary to devise a means of counting or at least of detecting *Drosophila* eggs in tomato products. The method depends upon separation of the eggs from the sample by shaking a

measured volume of the tomato product with a measured amount of gasoline in a separatory funnel, adding water, gently mixing, settling, and drawing off the portion containing the eggs. These are found, if present, by examining microscopically the material retained on filtration through a piece of bolting cloth. A magnification of about 10 diameters is used. See *National Canners Association Bulletin* 27-L, revised 1950, for details of method.

Brief reports on investigations on control of *Drosophila* on tomatoes will be found in the 1954 and 1955 annual reports of the research laboratories of the National Canners Association. Additional information is available from the Entomology Department of the University of California, Berkeley, California. Control is discussed briefly in Chapter 10 in the section on tomato canning.

Training of Laboratory Personnel. The estimation of mold fragments, worm and insect fragments, vinegar fly eggs, and other foreign materials by the microscopic examination of tomato products requires special instruction of personnel assigned to conduct such determinations. The research laboratory staffs of the National Canners Association, can-manufacturing companies' laboratory staffs, and the staffs of certain state university food or bacteriology laboratories give such instruction each summer to classes of limited size. The members of the classes are usually employees of tomato-products canneries. Application for enrollment must be made early in the summer. The course is usually repeated one or more times in order to accommodate all applicants qualified to take the instruction.

LABORATORY CONTROL

Value of Microorganism and Insect Counts. The foregoing considerations have shown the importance to the manufacturer of knowing at all times that his product conforms to the standards established by law for tomato products. For this reason, if for no other, a laboratory should be maintained for the inspection of every batch of tomato pulp or other tomato product.

Manufacturers of large quantities of pulp and catsup are finding it increasingly essential to know very definitely that their product is below the legal tolerance in content of worm and insect fragments.

Analyses of the pulp and finished products at the time of manufacture enable the plant superintendent to detect careless sorting and trimming at once or the arrival at the plant of tomatoes that carry excessive numbers of microorganisms. Of course, every load of fresh tomatoes should be critically inspected before it is accepted for products manufacture.

Specific Gravity and Refractive Index. In addition to examining tomato products microscopically, the chemist is of very great value to the tomato-

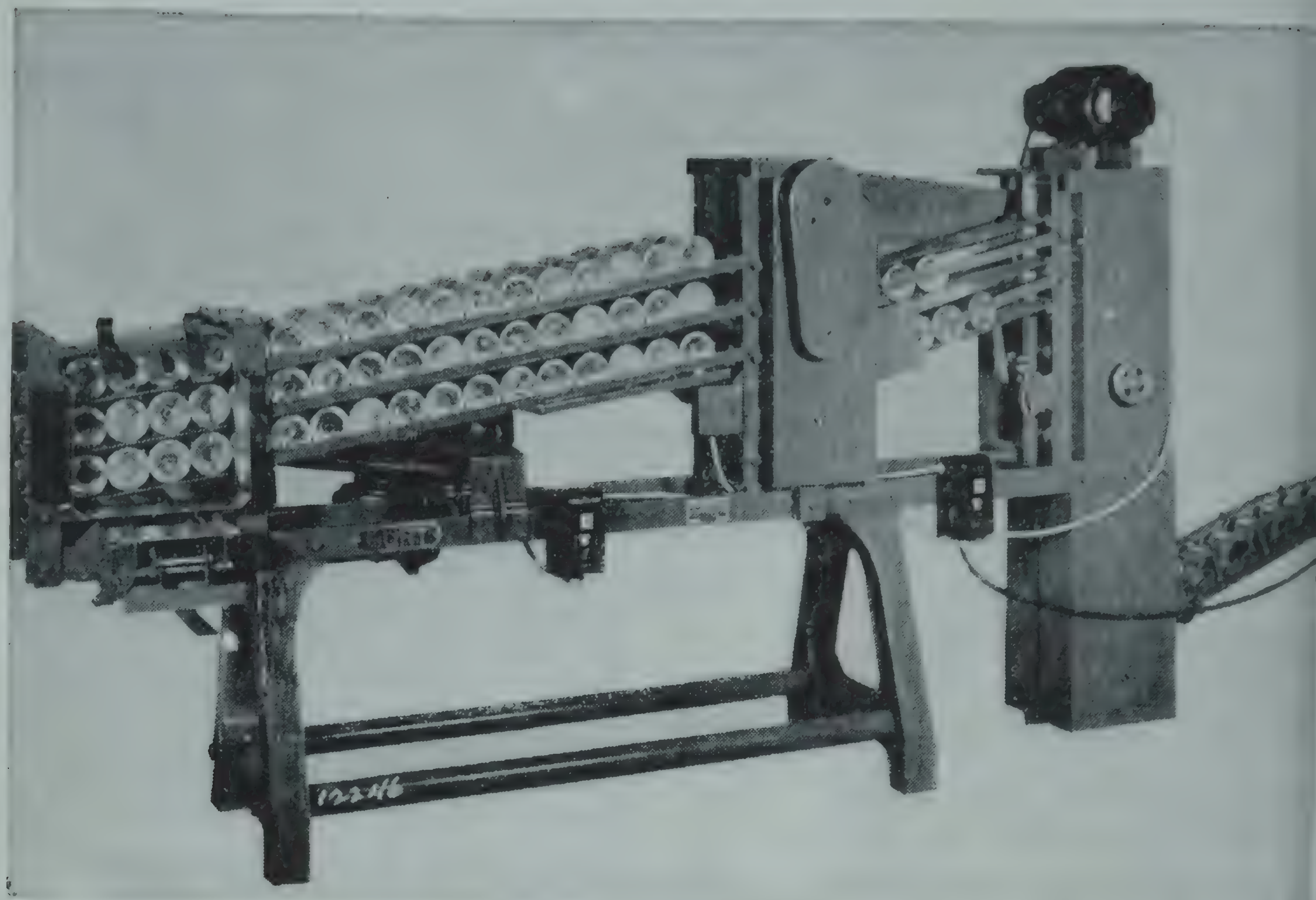


FIG. 83. High-speed case packer for canned food products. (*Burt Machine Co.*)

products factory in controlling the specific gravity of the pulp, etc. The average cannery workman cannot be trained to make reliable determinations of specific gravity or refractive index. Boiling the pulp to a definite volume, or use of some other more or less hit-or-miss method of determining the finishing point for pulp without laboratory control, leads to heavy losses in one of two ways. Either the product is liable to be frequently below the gravity demanded by the purchaser and a damage suit, rejection, or price penalty ensues; or the product is too highly concentrated and a low yield is thereby obtained, with consequent loss to the manufacturer and gain to the purchaser.

The magnitude of such loss may be indicated by the following consideration. If the manufacturer desires to produce purée of a specific gravity of 1.035 to fill a contract and, having no chemist, concentrates the purée to an average of 1.04, he will find that his yield will be reduced in the ratio of 100:114.7; that is, 114.7 gal. of pulp of 1.035 is equal to only 100 gal. of 1.04 specific gravity. On an output of 10,000 gal. of pulp per day this corresponds to a daily loss of 1,470 gal. In addition to the direct value of the chemist, there is the indirect increase in value of the product due to improved quality.

Other Determinations. Usually the total acidity and often the volatile acidity (acetic acid content) of tomato catsup are determined in order to make certain that sufficient acetic acid is present to balance the flavor and

to prevent rapid spoilage after the bottle is opened by the consumer. Measurement of the color of certain tomato products, or at least careful comparison of the color of each day's pack with that of a standard sample, is often essential.

Many plants measure the consistency of their tomato catsup frequently during the season, since this is a very important property of the product. Special instruments are available for this measurement. A simple test for factory-control purposes consists in measuring the time in minutes or seconds for a 50-cc. sample to flow from a pipette which has an outlet of rather wide diameter.

In some instances a determination of the per cent of insoluble constituents is necessary. The procedure is given in the *National Canners Association Bulletin* 27-L, revised 1950, and in the Association of Official Agricultural Chemists, "Methods of Analysis." Sugar is determined chemically by methods given in the latter or in other publications on methods of food analysis.

Most laboratories in tomato-products plants analyze samples of the tomatoes during the season for total solids by refractometer and for total acidity or pH value or both. Occasionally analyses must be made for spray or insecticide dust residues.

Measurement of color by one of the objective methods outlined in the section on color earlier in this chapter is now general practice in many tomato-products establishments.

Statistics. According to Magnuson Engineers of San Jose, California, about 25 per cent of the tomato crop of California is used for canning and about 75 per cent for manufacture of various tomato products. According to *Western Canner and Packer*, the production of tomato juice in the United States as a whole was 38,017,000 cases in 1956; in California 11,325,000 cases. Total United States production reached 32,754,000 cases in 1953.

The total United States pack of tomato catsup in 1956 was approximately 25,300,000 cases for catsup in glass containers and 4,967,000 cases in tin. The United States pack of tomato paste has ranged from 4,434,000 cases in 1954 to 9,557,000 in 1956; it was 6,787,000 in 1955. Canned purée production has ranged from 2,499,000 in 1954 to 4,768,000 cases in 1956; it was 3,307,000 cases in 1955. The production of canned hot sauce was 8,200,000 cases in 1951 and 10,378,000 cases in 1956, according to *Western Canner and Packer*.

REFERENCES

Association of Official Agricultural Chemists: "Methods of Analysis," 8th ed., Washington, D.C., 1955.

Ayers, S. H.: A gaseous fermentation of tomato catsup caused by yeast, *Glass Container*, **5**(4), 1926.

AYERS, S. H., and OSBORNE, E. G.: Temperatures in bottles after filling with hot catsup, *Glass Container*, **6**(3, 4), 1927.

BITTING, A. W.: "Appertizing, or the Art of Canning," The Trade Press Room, San Francisco, 1937.

BOHART, G. S.: Studies of Western tomatoes, *Food Research*, **5**, 469–486, 1940.

CAMERON, E. J.: Current suggestions on processing tomato juice, *Canner*, **102**(22), 40–43, May, 1936.

———: Spoilage of tomato products, *Canner*, **82**(22), 16, May 9, 1936.

CAMPBELL, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

CLELAND, T. M.: "The Munsell Color System," Universal Color Standards, Baltimore, 1931.

Control of flat sour spoilage in tomato juice, *American Can Co., Research Div., Spec. Bull.*, January, 1948.

COOPER, F. G.: "Munsell Manual of Color," Munsell Color Co., Inc., Baltimore, 1929.

DESROSIER, N. W.: Color grading foods with the Purdue color ratio meter, *Food Technol.*, **8**(4), 204–208, April, 1954.

DIXON, F. M.: Studies on consistency of tomato paste, *Natl. Canners Assoc., Research Lab., Spec. Pub.*, 1955.

Flat souring of tomato juice, *Continental Can Co., Research Dept., Bull.* 16, 1948.

FRIEDMAN, M. E., MARSH, G. L., and MACKINNEY, G.: On color in tomato products, *Food Technol.*, **4**(10), 395–398, 1952.

GOULD, W. A.: Simplified color instrument now available, *Food Packer*, November, 1954.

GURLEY, N. E.: Control of tomato products by refractometer, *Continental Can Co., Research Dept., Bull.* 11, 1946.

HARRISON, W. H.: The insect fragment count of tomato products, *Food Inds.*, **9**(5), 306–308, May, 1937.

HIER, W. G.: "The Manufacture of Tomato Products," Brock-Haffner Press, now Haffner Publishing Company, New York, 1919.

HOWARD, B. J.: Corn-ear worm in tomato products, *Food Inds.*, July, 1935, pp. 321–323.

———: Microscopical studies on tomato products, *U.S. Dept. Agr. Bull.* 581, 1917.

———: The sanitary control of tomato canning factories, *U.S. Dept. Agr. Bull.* 569, 1917.

JOSLYN, M. A.: "Methods of Food Analysis Applied to Plant Products," Academic Press, Inc., New York, 1950.

KERTESZ, Z. I.: Pectic enzymes of tomatoes, *Food Research*, **3**, 481–7, 1936.

KOHMAN, E. F.: Retaining vitamins in tomato juice, *Canning Age*, June, 1931, p. 263.

———: Vitamins in tomato products, *Ind. Eng. Chem.*, **22**, 1015–1018, 1930.

KRAMER, A.: This meter gives better color evaluation, *Food Inds.*, **22**, 1987, 1950.

MACGILLIVRAY, JOHN H.: Tomato color as affected by processing temperature, *Proc. Am. Soc. Hort. Sci.*, 1931, pp. 353–358.

———, MICHELBACHER, A. E., and SCOTT, C. E.: Tomato production in California, *Univ. Calif. Agr. Ext. Circ.* 167, June, 1950.

National Canners Association, Research Laboratory: Annual Report, 1950. See also reports for 1951–1956.

NICKERSON, DOROTHY: A method of determining color of agricultural products, *U.S. Dept. Agr. Tech. Bull.* 154, 1929.

OLSON, N. A.: Comparison of dye and A.O.A.C. method for counting eggs of vinegar fly in tomato products, *Natl. Canners Assoc., Research Lab., Spec. Rept.*, 1955.

PEDERSON, CARL S.: Types of organisms found in spoiled tomato products, *N.Y. State Agr. Expt. Sta. Bull.* 150, 1929; also *Tech. Bull.* 151, 1929.

——— and Breed, R. S.: Control of spoilage in tomato products, *N.Y. State Agr. Expt. Sta. Bull.* 570, 1929.

——— and ———: The preservative action in catsup of salt, sugar, benzoate and acid, *N.Y. State Agr. Expt. Sta. Bull.* 538, 1927.

Pratt, L. F.: Tomato juice manufacture and canning, *Canner*, **74**(5), 19–21, Jan. 16, 1932.

Robinson, W. B., Ransford, J. R., and Hand, D. B.: Measurement and control of color in the canning of tomato juice, *Food Technol.*, **5**(8), 314–319, August, 1951.

Saywell, L. G., and Cruess, W. V.: The composition of canning tomatoes, *Univ. Calif. Agr. Expt. Sta. Bull.* 545, December, 1932.

Smith, T. J., and Huggins, R. A.: Tomato classification by spectrophotometry, *Electronics*, January, 1952.

Strachan, C. C., and Atkinson, F. E.: Ascorbic acid content of tomato products, *Sci. Agr.*, **26**(2), 83–94, February, 1946.

Tomato products, *Natl. Canners Assoc., Research Lab., Bull.* 27-L, revised, 1950. Pulp, paste, and chili sauce, by W. D. Bigelow, H. R. Smith, and C. A. Greenleaf. Tomato juice, by C. W. Bohrer and J. M. Reed.

Townsend, C. T., Somers, I. I., Lamb, F. C., and Olson, N. A.: "A Laboratory Manual for the Canning Industry," National Canners Association, Research Laboratory, Berkeley, Calif., 1954 (revised 1956).

Tressler, D. K., and Joslyn, M. A.: "The Chemistry and Technology of Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

Troy, V. S.: Mold counting of tomato products, *Continental Can Co., Research Dept., Bull.* 10, 1946.

U.S. Department of Agriculture, Agricultural Marketing Administration: United States standards for grades of tomato juice, Aug. 29, 1938. Mimeographed circular. See also similar circulars for tomato paste, 1944; tomato purée or pulp, 1945; tomato catsup, 1953, and tomato sauce, 1954.

Whipple, S. R.: Color inspection: fresh fruits and vegetables, *Calif. State Dept. Agr. Bull.*, **64**(2), 47–55, April–June, 1955. Covers the Agtron.

Wilder, C. D., and Joslyn, M. A.: Estimation of worm and insect fragments in tomato products, *J. Assoc. Offic. Agr. Chem.*, **20**, 648–655, 1937.

Willstätter, R., and Escher, H. H.: Über den Farbstoffe der Tomate, *Z. Physiol. Chem.*, **64**(1), 47–61, 1910.

Worthington, O. J., Cain, R. F., and Wiegand, E. H.: Determination of color of unclarified juices by reflectometer, *Food Technol.*, **3**, 274, 1949.

Younkin, S. G.: Color measurement of tomato products, *Food Technol.*, **4**, 350, 1950. Also *J. Opt. Soc. Amer.*, **40**, 265, 1950.

CHAPTER 17

SUN DRYING OF FRUITS

The preservation of foods by drying is one of the oldest and most important of the food industries. In fact, considerably more fruit is preserved by drying than by any other means.

Until relatively recently, Asia Minor, Greece, Spain, and other Mediterranean countries produced most of the world's supply of sun-dried fruits; but California has now become the most important producer of raisins, dried peaches, prunes, and apricots. Although the date industry in that state is becoming important, the total production is relatively small compared with that of North Africa and Asia Minor.

New York and the Pacific Coast states produce the bulk of the dried apples in the United States, but this fruit is dried by artificial heat and not in the sun.

Extent of Industry in California. Except in California almost no fruit is sun-dried in the United States. The extent of the industry is indicated by the data in Table 34.

TABLE 34. PRODUCTION OF SUN-DRIED FRUITS IN CALIFORNIA, IN TONS

Fruit	1903–1907 average	1917	1921	1935	1945	1955
Apricots	8,200	15,000	6,500	25,800	7,800	14,300
Figs	3,000	2,000	6,500	24,000	24,800	25,300
Peaches	14,500	5,000	22,000	19,500	22,100	7,000
Prunes*	67,500	115,000	112,500	258,000	233,000	130,800
Raisins	54,000	163,000	122,500	203,000	242,000	220,000
Pears	No data	No data	2,500	5,000	5,400	2,300
Dates	No data	No data	1,000	3,250	400	16,500
Total	147,200	300,000	273.500	538,550	535,500	416,200

* Includes dehydrated.
SOURCE: *Western Canner and Packer.*

Advantages of Dried Foods. Dried foods are in more concentrated form than foods preserved in other ways. They are less costly to produce than

canned or preserved food, because of lower labor costs and because no sugar is required.

Dried fruit requires less storage space and a smaller number of cartons or boxes than an equivalent amount of fruit in canned or preserved form. A ton of apricots after canning weighs approximately 2,800 lb., if the weight of cans and boxes is included. A ton of fresh apricots yields about 400 lb. of dry fruit, which when packed will weigh not more than 450 lb., or less than one-sixth as much as the equivalent amount of canned fruit. With vegetables the difference in weight of the dried and canned articles is even more striking.

It can readily be seen that the cost of transportation will be very much less for dried than for canned, frozen, or fresh fruits and vegetables.

For these various reasons dried fruits are usually considerably less costly to the consumer than the equivalent quantities of canned, frozen, or preserved fruits.

EQUIPMENT FOR SUN DRYING

The equipment used for the drying of fruit varies considerably with the variety of fruit to be dried and with local conditions, but there are certain pieces of equipment that are common to several varieties of fruit.

The Dry Yard. Generally fruits are transported from the orchard to a centrally located yard to be dried, but the grape is usually dried in the vineyard between the rows of vines.

The term "dry yard" is usually taken to include both the area used for the trays of drying fruit and the buildings and equipment that are used in preparing and storing the fruit.

The area required for the dry yard varies with the variety of fruit to be dried, the yield per acre, and local weather conditions. Less area is required in a region where the temperature is high and the humidity is low than is required in a region of cool days and foggy nights. Under California conditions the ratio of the dry-yard area to bearing orchard or vineyard area is from 1:10 to 1:40 for prunes, with an average of about 1:20; for apricots, from 1:10 to 1:25, with an average of about 1:22; and for pears, about the same ratio as apricots except in localities where most of the drying is done under sheds, where the area required is less than for apricots. Peaches require about the same drying area as apricots, while figs require less drying space than apricots. Dates are usually allowed to dry on the trees or are dehydrated.

The dry yard should be protected from dusty roads, and the driveways in the yard should be sprinkled frequently or oiled to prevent the accumulation of dust on the drying fruit. The yard should not be near stables or other breeding places for flies. Bees and wasps become a serious pest during the

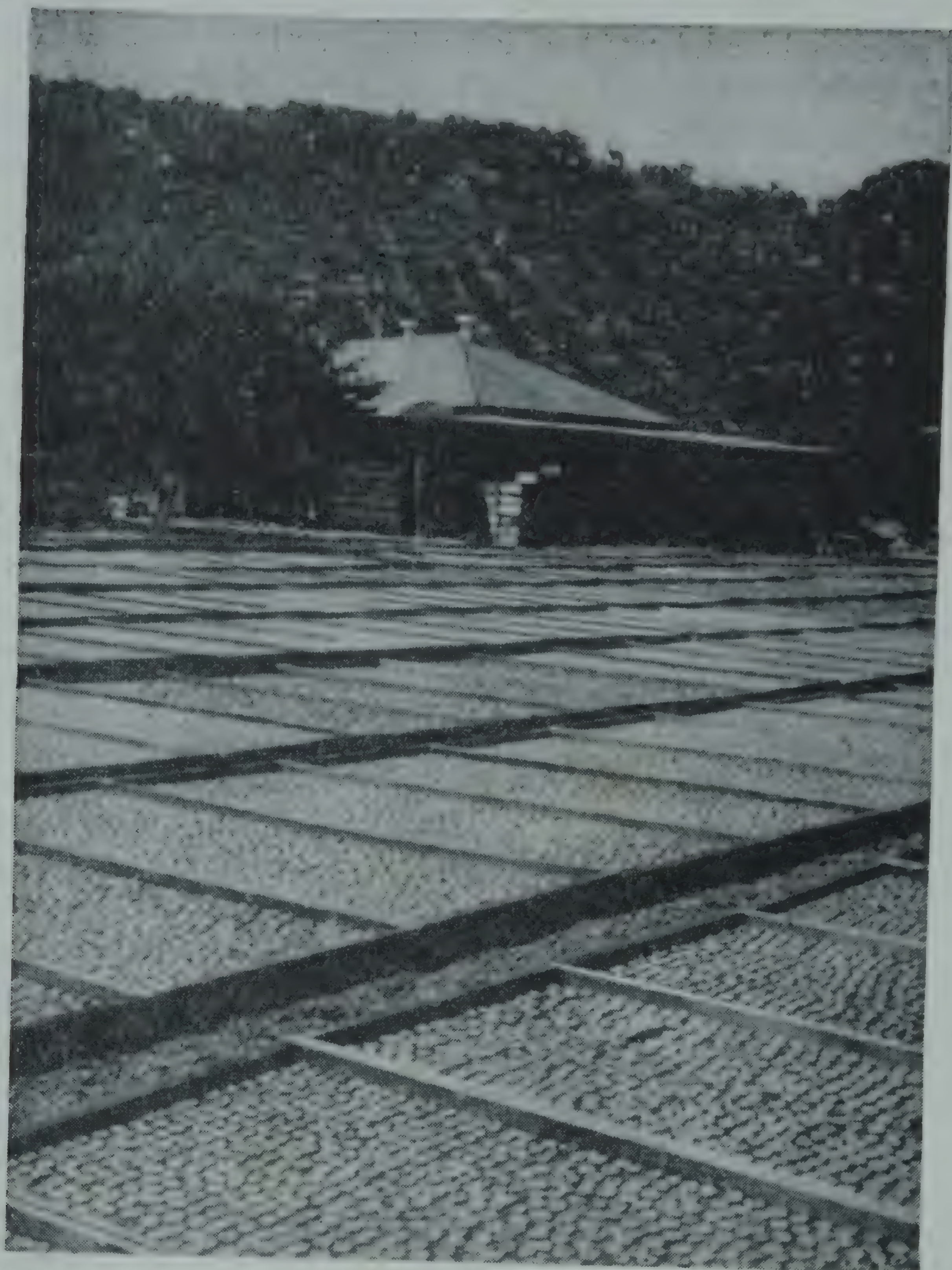


FIG. 84. Apricots on trays drying in the sun. Cutting shed and orchard in the background. (*California Prune and Apricot Growers' Association.*)

late summer and early fall months if the hives are near the yard. In very windy sections the yard should be protected by a windbreak.

The yard should be so designed with reference to the dipping and cutting sheds that the fruit can be handled efficiently, and it should be near the orchard.

Cutting and Dipping Shed. The fruit cutters and other workmen engaged in the preparation and traying of the fruit should be protected from the sun. An open shed, equipped in large yards with car tracks, cutting tables, and dipping equipment, is usually built for this purpose.

The shed should be so designed and equipped that the fruit may be carried through it during cutting, dipping, etc., in the most efficient and direct manner possible and with the minimum of confusion.

Sulfuring Equipment. Pears, peaches, and apricots are exposed to the fumes of burning sulfur before the fruit is placed in the dry yard. The usual sulfur house for peaches and apricots consists of a wooden, brick, or concrete chamber a few inches longer and wider than the trays and high enough to accommodate a dry-yard car loaded with 20 to 25 trays. The fruit is sulfured by burning sulfur in a small pit in the floor of the sulfur house or in a pan for the required length of time, which for most fruits is 3 to 6 hr.

A cheap and convenient form of sulfuring device is the "balloon hood," which consists of a light wooden frame covered with heavy roofing or building paper, or canvas made airtight with tar paint. This light chamber can be placed over a stack of trays in the dry yard, making the use of cars unnecessary. It is not very durable and is probably less convenient than the standard sulfur house.

Brick or concrete sulfur houses are permanent and more nearly fume-tight than wooden structures. It is desirable to equip the sulfur box with an adjustable opening in the roof to provide proper ventilation for continuous burning of the sulfur and distribution of the fumes. Success in sulfuring requires a fume-tight structure with adjustable air inlets and outlets. Trays must be so stacked that the fumes may reach all the fruit readily. The sulfur must be fresh and free of oil.

Placing the sulfur-burning pit at the rear of the sulfur box is desirable because the fumes from the pit then do not annoy the workmen so much during placing of the trays in the box and during removal of the car of trays after sulfuring. A small door is cut in the rear wall of the sulfur box to permit lighting of the sulfur in the pit. In some dry yards the sulfur is burned in a metal or stoneware box outside the sulfur house and the fumes are conveyed by natural draft or small fan into the sulfuring compartment.

Transfer Systems. The trays are usually transported in the yard by means of small cars on light steel rails. The cars are low and are fitted with wooden frames of the width of the trays. They are usually moved by hand.

Turntables or transfer cars and tracks are used for transferring the cars at right angles to the main track.

The track system should be carefully planned so that all portions of the dry yard may be conveniently reached and so that loaded cars may be transferred to the yard and empty cars from the yard to the preparation shed without confusion.

In some yards the trays are hauled on low-wheeled trucks by motor power or by horses. This method of transfer is more flexible than the track-and-car system but probably more costly in operation. In still other large yards lift trucks and pallets are used in moving the trays.

Trays. The tray universally used in California is made of pine or redwood shakes on a light wooden frame.

The sizes in most common use are as follows: 2 by 3 ft. with ends or sides

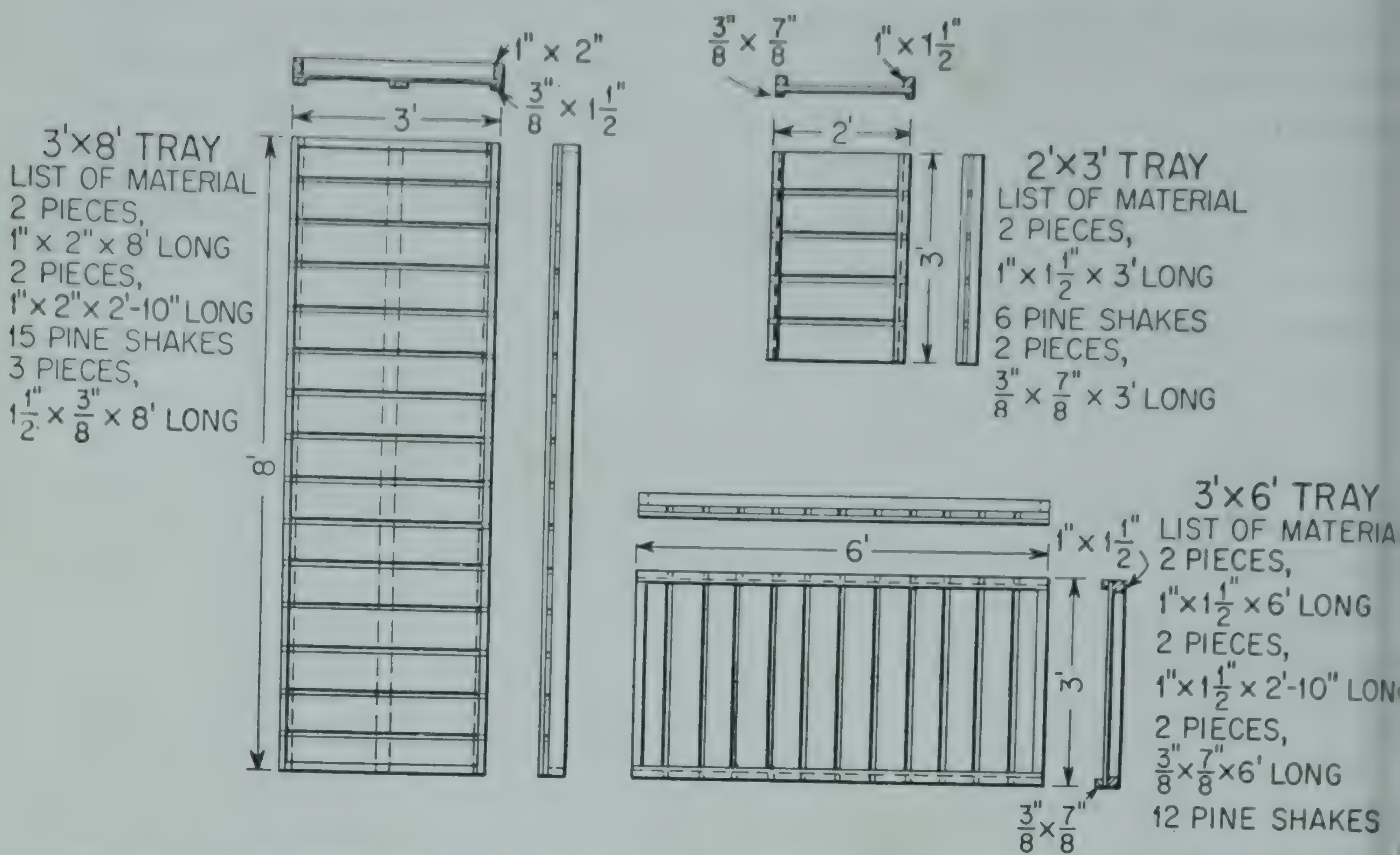


FIG. 85. Three sizes of sun-drying trays with lists of materials. (*Sketch by Barnard.*)

open, used for grapes and figs; 3 by 3 ft. with ends open, used for prunes and grapes; 3 by 6 ft., ends and sides usually closed, used for prunes, pears, grapes, apricots, and peaches; 3 by 8 ft., ends and sides closed, used principally for prunes but also for apricots, peaches, and pears.

The lists of materials for the 3- by 8-ft. and 2- by 3-ft. trays are as follows:

3- by 8-ft. tray

2 pieces, 1″ × 2″ × 8′
2 pieces, 1″ × 2″ × 2′ 10″
15 pine shakes, 6″ × 3′
3 pieces, 1½″ × ⅜″ × 8′

2- by 3-ft. tray

2 pieces, 1″ × 1½″ × 3′
6 pine shakes, 6″ × 3′
2 pieces, ⅜″ × ⅞″ × 3′

The appearance of the various trays is shown in Figures 84 to 86.

Cutting Tables. Peaches, pears, and apricots are cut in half and pitted or cored before being placed on the drying trays, which rest on a table in front of the cutters. In its simplest form the cutting table consists of two sawhorses or several lug boxes upon which the tray rests.

A well-built table is more rigid and convenient than the sawhorse or lug-box supports. A convenient cutting table devised by L. C. Barnard, of the University of California, consists of a frame 3 ft. in width and 8 ft. long. This will accommodate four 2- by 3-ft. trays, three 3- by 3-ft. trays, or one 3- by 6-ft. or 3- by 8-ft. tray. The top of the frame is at a convenient height for the cutters, about 33 in. from the ground. At the sides of the table are supports for lug boxes, from which the fruit can be readily taken to be cut and spread on the trays.

The cutting tables are movable and are placed in the cutting shed in such position that the fruit and trays may be carried to and from the tables conveniently. In several large dry yards the trays rest on a conveyer at convenient height for the cutters.

Boxes. The fresh fruit is usually transported to the dry yard in lug boxes holding 40 to 60 lb. of fruit.

The dried fruit is either stored in bins or is placed in sweatboxes, which are pine boxes about 10 in. deep and 3 by 4 ft. in size. Sweatboxes are more generally used for raisins than for other dried fruits.

Sanitation. The Federal Food and Drug Administration and the California State Board of Health are becoming keenly interested in cleanliness and sanitation in fruit-drying operations and dried-fruit storage facilities. Mrak and Phaff (1949) and more recently Vaughn and Mrak of the University of California have given important precautions that should be taken, which may be summarized as follows:

1. No fruit, or part of a fruit, should be dried which would not be considered edible in fresh form. "You can't make good dried fruit from bad fresh."

2. Cleanliness in all operations is absolutely essential. This includes cleanliness and care in picking, boxing, and delivering the fresh fruit to the dry yard, as well as handling and storage of the dried.

3. Trays must be kept clean. They should be soaked in an alkaline solution such as T.S.P. and washed thoroughly with a detergent and antiseptic solution before the beginning of the season. Scrubbing with a stiff brush is usually necessary also. Continuous mechanically operated tray washers are available for large dry yards.

Washing and drying of trays at the end of the season is also advisable. Oiling of new or clean, dry, used trays with a neutral highly refined colorless tasteless mineral oil will prolong their useful life and make for easier cleaning.

4. Washing of fruits before drying is advisable to remove dust. This is not feasible with grapes dried in the vineyard, however; prunes are washed during dipping before placing on trays.

5. Spray residues if present on the fruit must be removed by washing in suitable solutions, followed by rinsing with water. Unless this is done the dried fruit may be condemned by food and drug officials. The Entomology Department of the University of California can furnish directions for effective spray-residue removal. Some of the newer sprays require very special procedures.

6. Waste fruit (trimmings, rotten fruit, etc.) should be treated with chloride of lime, preferably in a pit, to prevent fermentation and breeding of vinegar flies and other insects.

7. Apricot pits are valuable and should be dried on a concrete slab or trays and not heaped up to provide a breeding place for insects.

8. Wash bowls, sanitary toilet facilities, and drinking fountains or disposable paper cups for drinking water should be provided, and the workers instructed to wash their hands frequently.

9. Workers should be instructed in how to cut and spread fruit properly and to observe cleanliness and care in their work. Nothing should be taken for granted in this connection.

10. Clean, sanitary storage is essential. See section on storage.

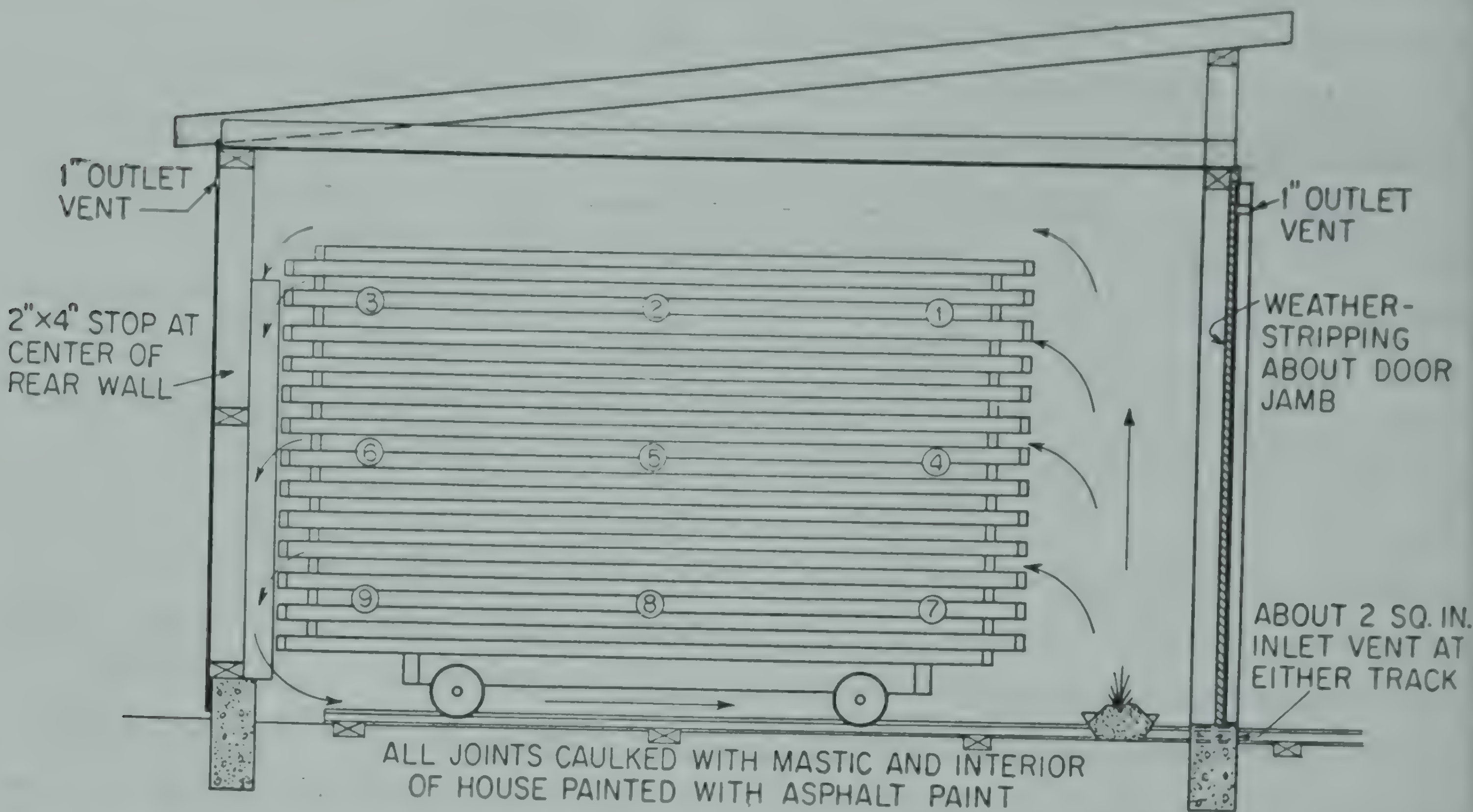


FIG. 86. Longitudinal section of a sulfur house, showing a car loaded with sun-drying trays, the location of the sulfur burner, and ventilation openings. (*After Phaff and Mrak.*)

11. Do not permit livestock, poultry, or pets in the dry yard, cutting shed, or storage room.

12. Encourage personnel to wear adequate head coverings.

Storage Space for Dried Fruit. Dried fruit must be protected from rodents and insects during storage. Therefore a room should be provided which is insectproof and which may be fumigated with methyl bromide or other suitable gas or vapor. See also the section on fumigation in Chapter 20.

The storeroom is equipped with bins, usually rectangular and 4 to 8 ft. deep, in which different lots of fruit may be stored separately. The front wall of each bin is made of removable boards to facilitate filling and unloading. In some cases the dried fruit is placed in heaps on the storeroom floor, and bins are dispensed with.

"Sweating" of the fruit, i.e., equalization of the moisture in the fruit and softening of the skins by moisture from the interior of the fruit, is considered an essential step in the process of drying and curing. The bins facilitate the sweating process.

Other equipment will be discussed under drying of the various fruits.

Rodent Control. Rats are very apt to contaminate dried fruit in bins by their urine and droppings. Regular fumigation in tight storage rooms can be used to advantage. Poison is usually too hazardous in a dried-fruit storeroom. Storage rooms should be screened to prevent entry of rodents. See also Chapter 26, Plant Sanitation.

Cold Storage. Dried fruits deteriorate rapidly at room temperature, both in color and flavor. Some of the better dry yards and dehydraters store their dried fruit at 32 to 40°F. until it is needed for packing. This prevents all insect and rodent damage, as well as darkening and loss in flavor. It is to be highly recommended.

Lye Dipping. Prunes, and in some sections grapes, are dipped in a dilute solution of sodium hydroxide, sodium carbonate, or other alkaline solution for the purpose of removing the wax coating and of checking or slightly cracking the skins of the fruit in order to increase the rate of drying.

The simplest form of lye-dipping apparatus consists of a heavy cast-iron kettle filled with dilute lye solution and mounted over an oil-burning furnace. The fruit is dipped in the kettle of boiling lye solution by means of a small woven-wire basket holding 25 to 50 lb. of fruit.

A very common form of dipping outfit used by small dry yards consists of a brick furnace about 6 ft. high in which is set a rectangular sheet-metal tank containing the lye solution. At one side of the dipping outfit is an unloading platform on which the lug boxes of fresh fruit are placed and on which the workman who operates the dipping outfit stands. A rectangular basket with rounded bottom holds the fruit during dipping and is operated by a hand lever. A second tank and a second basket may be placed beyond the first basket for rinsing the lye-dipped fruit. Prunes are usually not rinsed, whereas grapes are generally thoroughly rinsed to remove all adhering lye solution. The lye tank is generally heated by an oil burner (Figure 87).

Continuous dipping machines are used in most large dry yards. The spray type of lye peach-peeling machine has proved very satisfactory for dipping prunes and grapes for drying.

Sodium hydroxide is generally used in preference to other alkaline substances in the dipping solution, although sodium carbonate and mixtures of sodium carbonate and sodium hydroxide are used to a limited extent. Sodium bicarbonate is sometimes used for the dipping of Sultana grapes, but its action is not severe enough for prunes or tough-skinned grapes. For dehydration prunes are now often dipped in hot water only before drying.

The concentration of the lye-dipping solution varies according to the variety of fruit, its maturity, and the district in which the fruit is grown. The maturity of the fruit also affects the strength of the solution necessary

to check the skins satisfactorily. Green fruit requires a more concentrated solution than ripe fruit of the same variety. Prunes grown in the hot interior valley of California require stronger solutions for dipping than those grown in the coastal counties.

PRUNES

Previous to 1918 almost the entire prune crop in California had been dried in the sun. In 1918 the industry suffered a loss of approximately 5 million dollars because of early fall rains that caused the spoiling of the fruit on the trays. Since that date, interest in the use of dehydraters has increased, and at present practically the entire crop is being dried by artificially produced heat.

Varieties. The French prune (*Petite Prune d'Agen*) is the principal variety grown in California. The trees of this variety produce regularly and heavily, but the fruit is smaller than that of most other varieties grown commercially in California.

The Sugar prune, the second in importance in California, is larger than the French prune and ripens several weeks earlier than the latter. The skin of the Sugar prune is more tender than that of the French prune and therefore more easily checked in lye dipping. It molds and ferments more readily than the French variety and for this reason requires more care during drying, and it does not bear so heavily as the French prune.

The Imperial prune is a very large variety, but the tree does not bear so regularly or so heavily as the French variety. It is a very difficult fruit to dry successfully in the sun, because of fermentation and darkening of the flesh near the pit, but when properly dried, it commands a premium because of its large size. It can be dehydrated easily, a fact that should eliminate the principal objection to it.

The Robe de Sargent is a variety grown in limited quantities only. It is less desirable than the French prune, since it is no larger than the latter and usually contains less sugar.

Several selected and new strains of the French prune are being advocated at the present time by nurserymen. The most promising of these new strains is probably the Coates "1418" prune.

The Silver plum is sulfured and dried in the sun to a limited extent.

The Italian prune is not grown commercially in California for sun drying, although it is the principal variety grown in the Northwest for canning, freezing, and dehydrating purposes.

Harvesting. In California, prunes are usually allowed to ripen on the tree and to fall to the ground of their own accord. They are then picked from the ground by hand into lug boxes. At the end of the season fruit that has not ripened sufficiently to fall of its own accord is shaken or knocked from

the trees, but this fruit is not so sweet or of so good a color as that which ripens and falls naturally. In several localities, however, shaking of the trees by machine or knocking the fruit from the trees with poles is necessary. Mechanical harvesting is also used.

The fruit should not be allowed to lie on the ground too long, because it is liable to mold or become partially dried and hence difficult to check by lye dipping. The use of special machines for picking up the prunes from the ground is increasing.

The orchard soil should be rolled at the beginning of the season so that the fruit will be injured as little as possible and picking facilitated.

Usually four to five pickings are made during the season.

Dipping and Size Grading. At the dry yard the prunes are dumped from the lug boxes into the dipping machine. For French prunes the lye solution varies from 0.25 to 1.5 per cent, according to the maturity of the fruit and the locality. In the Sacramento Valley the stronger solution is used; in the Santa Clara Valley and other coastal regions, solutions of approximately 0.5 per cent are generally employed. The above percentages correspond to about 4 to 12 lb. of lye per 100 gal. of water. For dehydration, prunes are often dipped in boiling water.

Length of Dipping. The prunes remain in the lye solution from 5 to 30 sec., the average time being approximately 15 sec. The rotary automatic dipper is used in the large yards and the hand-power basket dipper in the small yards.

Sugar prunes require a weaker lye solution than French prunes and a shorter period of dipping. The Imperial prune is more tender than either the French or Sugar varieties and is dipped in a very dilute solution (0.25 per cent) or in boiling water only. Some growers place Imperial prunes undipped on the trays in the sun for several days before dipping, in order to shrivel and toughen the skins slightly.

Needle Board. At one time most prunes were passed over a needle board after dipping, in order to puncture the skins. This practice has now been discarded in most yards.

Size Grading. Prunes should be graded for size after dipping, in order to promote uniformity of drying, because much of the small fruit is partially dried before it arrives at the yard and becomes overdried if mixed with the larger fruit. In most yards two or three grades only are made. In some yards the slabs or culls are separated from the remainder of the fruit by hand and dried on separate trays.

Appearance of Dipped Fruit. A properly dipped prune should exhibit very small cracks over its entire surface; the skins should not be partially peeled from the fruit nor should any great proportion of the fruit pass through the dipper without checking of the skins. If the solution is too weak, the prunes must be submerged in the lye for such a long period that

many of them become partially cooked and some burst or are partially peeled. If the lye solution is too strong, the fruit is apt to be partially peeled or the cracks in the skin become too large. It is desirable that the solution be maintained actively at the boiling point for the best result.

Renewing the Solution. In most yards the lye solution is replenished from time to time during the day by the addition of fresh lye in granular form and by adding water to replace that lost by evaporation, neutralization, and adhering to the fruit. It becomes necessary to remove the lye solution

Fig. 87. Dipping outfit and tray-spreading rack for prunes. (*Food Machinery Corp.*)

occasionally and to replace it with freshly prepared solution because of the accumulation of sugar, dust, and salts of sodium.

Rinsing. Prunes are generally not rinsed after dipping, although rinsing improves their appearance.

Traying. The dipped prunes fall from the grader or dipper to trays placed in the proper position to receive the fruit.

The tray most commonly used is 3 by 8 ft. in size. When the prunes are placed one layer deep the tray holds approximately 75 to 90 lb. of fruit. The fruit is spread by hand or in some yards mechanically.

The loaded trays are stacked on a waiting dry-yard truck, usually about 20 trays per truck, and taken to the dry yard.

Spreading and Drying in the Sun. The trays are spread in rows on the ground as shown in Figure 84, with pathways between the rows to permit handling of the fruit and tray during drying.

Sugar and Imperial varieties usually require stirring to prevent molding, after the fruit has been on the trays for 3 or 4 days.

Stacking. After the prunes have become two-thirds to three-fourths dry, the trays are stacked one above the other in such a manner that the air may pass freely between the trays, and drying is allowed to continue in the stack. Much of the fruit dried completely in the sun is apt to be overdried.

In good drying weather the trays may be stacked within 4 or 5 days after dipping.

Removal from the Trays. The fruit is dried to a moisture content of approximately 12 to 18 per cent. The grower determines the end point by the feel of the fruit. The pit in a properly dried prune should not slip between the fingers when the prune is pressed; the texture should be leathery and the flesh firm. The prunes should not be so dry that they rattle on the trays. Overdried fruit results in low yields, while underdried fruit will spoil or "sugar" in the storage bins.

The fruit is carefully sorted before it is removed from the trays in order to remove bloaters (insufficiently dried immature fruit), slabs (broken or overripe fruit), and split or otherwise damaged fruit.

The remaining fruit is then scraped from the trays into lug boxes and transported to the storage bins or to a commercial packing house.

Sweating. The dried fruit is placed in bins built for the purpose or is heaped in piles on a clean floor to undergo sweating, or equalization of the moisture. The overdried fruit absorbs moisture from the fruit of higher moisture content, and the surface of the fruit becomes moist through the diffusion of moisture from the interior of the fruit to the surface.

Sweating usually lasts 2 weeks or longer. In some yards sweating is dispensed with and the fruit is taken direct to the packing house from the dry yard in lug boxes or sacks. As previously stated, the storeroom should be rodentproof and tight enough for fumigation. Dried prunes keep much better in cold storage.

Delivering to Packing House. The sweated fruit is usually placed in bags for transportation to the packing house, where the fruit is weighed and samples are taken for the door test, which consists in noting quality, taking moisture content, and counting the number of prunes per pound. The grower is paid on this basis. Further information concerning size grades will be found in Chapter 20.

Yields. In California the normal drying ratio for French prunes is about 2.41:1; that is, 2.41 lb. of fresh fruit is required to produce 1 lb. of dry. Yields as high as 1.8:1 and as low as 3:1 are obtained, depending upon the maturity of the fruit.

The average yield of dry fruit per acre of bearing orchard is about 2 tons. It is apt to be higher than this in irrigated orchards and lower in non-irrigated.

Silver Plums. Silver plums, or Silver "prunes," a large white variety of plum, are dried in California to a limited extent. The plums are lye-dipped,

as described above for other varieties of prunes, are placed in the fumes of burning sulfur for at least 4 hr., and are then placed in the sun to dry. The drying operations are similar to those for other prunes. The dried product is of amber color and of acid flavor.

Rain Damage. In years of early fall rains, loss from rain may be serious. In such a contingency the trays should be stacked before rain begins and covered to prevent wetting of the fruit. If the rain is not prolonged, the trays may be spread in the sun later to complete the drying. If the rain is prolonged for several days, it will be necessary to complete the drying process in a dehydrater or to expose the prunes on the trays to fumes of burning sulfur for 30 to 40 min. to prevent molding and fermentation.

SUN DRYING MUSCAT GRAPES

The drying of raisins is the most important fruit-drying industry. California, Australia, Greece, Asia Minor, and Spain produce most of the raisins of the world. Greece is noted for its dried currants, a small raisin made from currant grapes (not currants in the ordinary sense of the word). Spain produces principally Muscat, also known as Malaga, raisins, and several varieties of seedless raisins are dried in Asia Minor. Smyrna is one of the most important ports for the shipment of raisins from Asia Minor.

Cooperative Association in California. The raisin growers of California in 1912 organized a cooperative marketing organization to market the 70,000 tons of raisins produced in the state at that time, which were then selling at a loss. An advertising campaign resulted in selling all the surplus and in placing the raisin-growing industry on a paying basis. Since that year the planting of vines has increased rapidly until at the present time California is producing approximately 220,000 tons of raisins annually.

The growers harvest and dry the grapes and may also sort out cluster raisins before delivery. The raisins are then delivered by the growers to the association's packing plants or receiving stations. Payment to the extent of not more than 50 per cent of the value of the raisins is made to the growers by the association within 6 days after delivery. Final payment is made after the fruit has been sold, or at intervals during the year after receipt of the raisins at the packing houses.

The production of raisins in California was 220,100 tons in 1955, according to *Western Canner and Packer*, and 165,300 tons in 1954. It reached 301,300 tons in 1947. The usual production is 220,000 to 230,000 tons per year.

The association makes a contract with the growers for a period of several years. This contract has been proved in court to be binding on both parties. It gives stability to the organization and is undoubtedly one of its more important features.

There are several large independent packers of raisins. Also, there is in force at present (1956) both state and Federal marketing agreements. One purpose is to increase the consumption of raisins in the United States, and another is to facilitate their export. Under the Federal agreement some support of the price for raisins is given when necessary. Information on the agreements may be had from the California State Department of Agriculture, Sacramento, California, and from the U.S.D.A.

Relation of Maturity to Yield and Quality. It is customary to begin harvesting the Muscat grape for drying in California at about 21° Balling, i.e., when the juice expressed from the grapes tests 21° by the Balling hydrometer. Bioletti has made a thorough study of the effect of maturity on yield and has obtained rather startling results. His experiments have been confirmed by F. K. Howard, H. E. Jacob, and others. Table 35 illustrates the results obtained.

TABLE 35. EFFECT OF MATURITY ON THE YIELD AND RETURNS FROM MUSCAT GRAPES*

Balling of juice at time of picking	Pounds of raisins per acre	Gross returns per acre	Cost per acre	Net profit per acre	Increase in profit per acre, per cent
18	1,786	$ 89.30	$47.90	$41.40	0.00
19	1,893	94.65	48.70	45.95	8.57
20	2,000	100.00	49.50	50.50	21.98
21	2,107	105.35	50.19	55.16	33.24
22	2,214	110.70	50.88	59.82	44.49
23	2,321	116.05	51.57	64.48	55.75
24	2,428	121.40	52.26	69.14	67.00
25	2,535	126.75	52.95	73.80	78.26
26	2,642	132.10	53.64	78.46	89.52
27	2,749	137.45	54.33	83.12	100.77
28	2,856	142.80	55.02	87.78	112.03

* At 5 cents per pound for raisins. Prices are much higher at present; nevertheless, the data are useful since they show the effect of maturity on yield.

SOURCE: After Bioletti.

From these results it can readily be seen that it is extremely important that grapes for drying should be fully matured. The principal reason that grapes are picked before they have reached their maximum sugar content is that, because of labor shortage, it is often difficult to pick all the grapes before there is loss from early fall rains. Now, however, many growers are ensuring against rain damage by erecting dehydraters to be used during seasons of early rains. Where this provision is made, it is possible to delay harvesting until the grapes have attained at least 24 to 25° Balling. Grapes harvested when immature yield not only a smaller total amount of dried

product but also raisins of smaller size and of poorer texture and color. Jacob (1942) has greatly extended Bioletti's studies.

Preparing Vineyard for Drying. The rows of vines usually lie in an easterly and westerly direction, in order that the trays may not be shaded during the morning and afternoon. A furrow is sometimes plowed on the north side of the row, in order that the trays may be tilted toward the south and thus receive the full rays of the sun. The forming of this furrow is known as "V-ing."

Harvesting. After the furrow has been made and the grapes have attained the desired maturity, the trays, 2 by 3 ft. in size, are taken to the vineyard and distributed to the different rows. The grapes are picked directly onto the trays, which are placed between the vines and are tilted toward the south. In most vineyards approximately 22 lb. of fruit is placed on each tray.

The grapes must be spread evenly and to a depth of one bunch only. Picking is done by piecework.

A short knife with curved blade or a pair of stout, short shears is used for cutting the bunches of grapes from the vines.

Paper Trays. Most seedless grapes are now dried in California on short pieces of heavy wrapping paper. When the grapes are nearly dry, the "trays" are rolled into tight "sausages" and left in the open a few days longer to complete drying. While convenient and inexpensive, the paper trays do not protect the raisins against heavy rain, which may cause heavy damage or complete loss. When the grapes are partially dry they may be transferred to another paper tray in order to turn the bunches. Insect infestation in the rolled trays of raisins is sometimes severe.

Turning. After the grapes have partially dried, the wooden trays are turned by placing an empty tray over a filled tray, then quickly and deftly reversing the trays and removing the empty tray. The bottoms of the bunches are thus exposed to the sun, and drying is hastened and made more uniform. Under usual drying conditions about 4 to 6 days' exposure to the sun is required before the grapes are ready to turn.

Turning should be carefully done, so that the bunches will be broken as little as possible and a maximum yield of cluster raisins obtained, if the grapes are of the Muscat variety.

Stacking. As in the drying of other fruits in the sun, the last stages of the drying process are conducted in the shade, i.e., by stacking the trays in order to protect the fruit against the direct rays of the sun. Stacking is done when it is no longer possible to express juice from the berries by pressure between the fingers, which normally will be 5 to 6 days after turning. The grapes are left in the stack until sufficiently cured to be accepted by the packing house, usually after about 1 week in the stack. The total drying period under normal drying conditions is therefore about 3 weeks. In cool

weather 6 weeks may be required to dry the grapes sufficiently, and in very hot weather less than 3 weeks.

Placing in Sweatbox. There is a good demand for Muscat raisins in the bunch for fancy packages for the holiday trade. These raisins are used for dessert purposes and are known as "layers," or "clusters." The grower is paid a premium for such fruit. When the grapes are dry (about 15 to 17 per cent moisture), the trays are sorted to remove the large and perfect clusters, which are placed in sweatboxes, care being taken not to break the bunches.

Raisins not suitable for clusters are dumped into sweatboxes. The raisins are very easily removed from the trays because there is no tendency for the fruit to stick to the smooth wooden shakes used for tray bottoms and because the grapes are not dipped and therefore do not exude juice or sirups, as do prunes and cut fruits.

Sweatboxes. Sweatboxes are almost universally used as containers for the raisins. These boxes are approximately 3 by 4 ft. and about 10 in. deep, about 150 lb. of raisins being placed in each sweatbox. By pressing the raisins, the box can be made to hold a larger quantity, but this practice is objectionable because it may result in breaking of the berries and stems, making it difficult to stem the raisins in the packing house.

The raisins should be left in the sweatboxes for at least 3 weeks before delivery to the packing house in order that they may equalize in moisture content and remain fairly constant in moisture content during storage at the packing house.

SUN DRYING SEEDLESS GRAPES IN CALIFORNIA

Seedless Grapes in California. The principal seedless variety grown in California is the Sultanina or Thompson Seedless, which comprises more than 90 per cent of the total crop of seedless grapes in that state. The Sultana is second in importance. Two varieties of currant grapes, the Black Corinth and the White Corinth, are grown in very small quantities.

Natural Undipped Sultanina. The Fresno district is the principal producer of Thompson Seedless raisins, where most of the seedless grapes are dried in the same manner as described above for the Muscat grape. The grapes are not dipped in lye or otherwise treated before drying, but are picked direct from the vines on the trays. In most vineyards paper trays made of heavy wrapping paper of the same dimensions as the wooden trays are used. They are much less satisfactory than the wooden trays, their only merit being low original cost.

Thompson seedless grapes should not be picked until the juice has attained at least 24° Balling, although in a late season attainment of this ideal may not be practicable.

Because of the larger size of the bunches, a larger weight of Sultanina grapes than of Muscats can be placed on each tray. The Sultanina yields more heavily than the Muscat, and plantings of this variety have been much heavier than of Muscat.

Professor A. J. Winkler of the University of California has stated that the quality of the grapes and raisins is suffering in many vineyards because growers force the vines to bear such heavy crops that the grapes do not mature properly.

Soda-dipped Sultanina Raisins. In the Sacramento Valley of California, grapes ripen 2 to 3 weeks later than in the Fresno district in the San Joaquin Valley. Therefore most of the grapes are lye-dipped in order to hasten completion of drying before the rainy season. The Sacramento Valley produces very few grapes at present, because phylloxera has destroyed many of the vineyards. Soda-dipped raisins are now practically a thing of the past in California, but the procedure is given for the sake of completeness. A similar product is made in Australia.

Lye Solution. At the dry yard the grapes are dipped in a boiling dilute lye solution in a manner similar to that described elsewhere for prunes. The concentration of the lye varies from about 0.1 to about 0.75 per cent sodium hydroxide, the most desirable concentration being about 0.5 per cent; or a mixture of sodium carbonate and sodium hydroxide is used in some yards. The length of immersion in the lye solution is from 3 to 6 sec., and the grapes are rinsed in water immediately after lye dipping.

Dipping Outfits. The "merry-go-round" dipper, the most commonly used type of dipping outfit, consists of two or more hinged wire baskets suspended from the ends of levers, which in turn are hinged to a central pivoted upright. The baskets are filled with grapes, immersed in the boiling lye solution a few seconds, and rinsed in water, and the grapes are spread on 6- by 3-ft. trays.

The skins of properly dipped grapes should exhibit an evenly checked surface.

Spreading in Yard. The trays are spread in the dry yard directly from the dipping shed and are turned after the grapes are from one-half to two-thirds dry, in normal drying weather 3 to 5 days after dipping. After 2 or 3 days' further exposure the trays are stacked to complete the drying process.

After drying, the raisins are transferred to lug boxes or sweatboxes and taken to the stemming and packing house, which is frequently part of the dry-yard equipment. The raisins are light brown in color and superior to the bleached raisins in flavor.

Oil-dipped Sultanina and Sultana Raisins. So called "oil-dipped" raisins are prepared by dipping the fresh grapes in a cold solution of sodium bicar-

bonate on the surface of which is a thin layer or film of olive oil. The usual concentration of bicarbonate is 28 lb. per 100 gal.

This solution does not check or crack the skins of the grapes and apparently merely removes the wax and bloom. The grapes are coated with a very thin film of oil as they emerge from the dipping solution. This causes the dried product to be light in color and of glossy appearance.

The grapes are dried in the sun, as previously described for lye-dipped Sultanina grapes. Oil-dipped raisins are very seldom produced in California, but are common in Australia.

In California the Sultana and Sultanina are different varieties. In Australia the grape known in California as the Sultanina is called the Sultana.

Bleached Sultanina Raisins. There is a considerable demand among the Jewish population of the Eastern United States for bleached seedless raisins, prepared by exposing lye-dipped Sultanina grapes to the fumes of burning sulfur for 3 to 5 hr. before spreading in the dry yard. Drying is conducted as described for the soda-dipped raisins.

A perfect specimen of bleached Thompson Seedless raisins should be translucent and white to very light amber in color. It should be dried sufficiently so as not to exude sirup when pressed between the fingers, but should be tender, not brittle or tough. The flavor of the bleached raisins is not so pleasing as that of the unsulfured fruit.

Bleached seedless raisins are now usually dehydrated rather than sun-dried.

Drying Grapes in Australia. The process of drying grapes in Australia is described as follows by H. F. Levien, a prominent grape grower of Renmark, South Australia.

The following classes of raisins are produced: currants, Sultanas (lye-dipped), Muscats (not dipped), and Muscats (lye-dipped). Lye-dipped Muscats are known as "lexias," an adaptation from the Spanish.

The hot dipping solution for seedless grapes is usually the so-called "mixed dip," consisting of 2½ lb. of potassium carbonate, 2 lb. of sodium hydroxide, 1½ pt. of olive oil, and 50 imperial gal. of water. The grapes are dipped at 178 to 181°F. and spread on trays or racks to dry.

Muscat grapes are usually dipped in a solution of 1 lb. of sodium hydroxide to 12 to 16 gal. of water at about 200°F. They are drained well and spread to dry.

Neither the seedless nor the Muscats are dipped sufficiently to crack the skins noticeably, whereas in California the dip is more severe, resulting in cracking of the skins.

At one time raisins were made by sun drying on 2- by 3-ft. trays, as in California, but owing to the heavy losses from rains and to the labor cost

of stacking trays in inclement weather, a process peculiar to Australia has been developed. The grapes are dried on wire-netting racks beneath a sheet-metal roof or wooden shed. Wire netting of 2-in. mesh and 18 gauge is "strung," i.e., fixed to heavy 6-gauge wire to give it rigidity, and is fastened to posts by fixed or removable frames. Six or more tiers of the netting are used.

Currants are spread on the screens without dipping. Muscats (Muscat Gordo Blanco) and Sultanas are usually dipped in a dilute boiling lye solution and rinsed before spreading on the netting racks. Some Muscats are dried without lye dipping. A perforated metal bucket is used in spreading dipped grapes. Lug boxes are used for currants, as these are not lye-dipped.

The fruit is not exposed to the sun but is dried by air currents, which circulate freely between the racks. Currants require 14 to 21 days for drying, lye-dipped Sultanas about 10 days, and Muscats about 14 days. Undipped Muscats and Sultanas require considerably longer periods.

The color of raisins dried on racks is very attractive, is lighter than that of raisins prepared by sun drying, some of the green color of the fresh grapes often being retained, and the flavor is excellent.

The seedless grapes are also dried after dipping in a cold potash solution containing about ½ lb. of potassium carbonate per gallon of water and ½ to ¾ pt. of olive oil per 25 gal. of solution. The oil is thoroughly emulsified with the potash solution. The grapes are immersed in the solution for 2 to 5 min. at about 100°F. and are then dried on racks or trays. They are usually sprayed occasionally with dilute potash solution during drying. When dry, they are spread in the sun for a few hours to bleach the chlorophyll. They are then rinsed in water and dried in the sun to remove surface moisture.

The average yield of Muscat raisins per acre is about 1 ton, of Sultana about 1,800 lb., and of currants about 1½ tons. With improved methods of cultivation and care, it is possible to double the average yields.

The Australian raisins are marketed principally in England, New Zealand, and Australia, but increasing production will undoubtedly force the growers to seek additional markets.

The dried-fruit producers of Australia are organized under the name of the Australian Dried Fruit Association and use the trade-mark Sunraysed.

Sun Drying of Wine Grapes and Cull Table Grapes. During the Prohibition period in the United States there was a demand for dried wine grapes for the preparation of homemade beverages. Wine grapes, principally of the red-wine-grape varieties, have been dried on an extensive scale in the raisin districts of California without previous treatment, by the same methods now in use for the drying of Muscat and Sultanina. Sun-dried grapes produced by this method yield on soaking in water a juice of dark brown, not red, color, whereas consumers of these grapes desire a red juice

for beverage purposes. In experiments made by the author at the University of California Farm, it was found that the red color could be retained by dipping the grapes in lye and exposing the dipped grapes to the fumes of burning sulfur for about 1 hr. before drying. Wine grapes require a 2 to 3 per cent lye solution for satisfactory checking of the skins.

While cull table grapes from the fresh-fruit packing houses are utilized for the manufacture of wine and brandy, they also are now sometimes dried in the sun or in dehydraters after lye dipping and have sometimes found a market as cheap raisins.

SUN DRYING OF FIGS

Smyrna has long been known as the world's principal fig-exporting port. The fruit is produced in several districts of western Asia Minor. In recent years the production of dried figs in California has rapidly increased, and California is now a strong competitor of Smyrna in the markets of the United States.

Varieties of Figs for Drying. The so-called "fruit," the fig, is the fleshy receptacle enclosing a large number of very small flowers which develop into small seeds as the figs ripen. The Smyrna fig (more properly, Lob Injir), a large white variety, is the principal variety grown in the Mediterranean countries for drying. It requires fertilization with the pollen of some other variety, accomplished by a small wasp which develops inside a male variety of fig grown for pollination purposes and known as the caprifig; on emergence from the latter, the insect carries on its legs and body pollen from the flowers of the caprifig, which are borne inside the fig. The insect, known as *Blastophaga grossorum*, escapes through the small opening in the blossom end of the caprifig, enters the eye of the immature Smyrna fig, and pollinizes it. The Smyrna fig does not develop or ripen unless pollinized in the manner described above. The caprifig remains on the tree during the winter and serves as an abode for the *Blastophaga*, a fact that prevents extermination of the insect after the removal of the figs from the Smyrna trees.

The Smyrna variety is large, has an excellent flavor, and is attractive in appearance when packed. An objection to this variety when grown in a cool climate is its tendency to ferment, rot, and sour before drying.

"Calimyrna." A strain of the Smyrna variety is grown in California under the name of Calimyrna. Its successful culture has been made possible by the studies of George Roeding of Fresno and G. P. Rixford of the U.S.D.A. In recent years losses of the fruit in the orchards have been very heavy because of endosepsis, a disease carried into the figs by the *Blastophaga* wasp. Smith and Hansen of the University of California have devised a means of securing disease-free wasps and propagating them in quantity. Its successful

use depends also on destruction of all contaminated figs and wasps, a rather costly and troublesome procedure, though not impossible of attainment.

Adriatic. The Adriatic fig is a white variety of pink flesh. It requires no artificial pollinization; a large proportion of the seeds are sterile. It is inferior in size and flavor to the Calimyrna variety but is a heavy bearer and is grown extensively on that account.

Kadota. The Kadota (according to Coit and Condit, the Dodatto) is a white variety now planted extensively in California for fresh shipment and for canning and preserving. It is on the average smaller in size than the Calimyrna and Adriatic varieties and requires no pollinization. It is the most satisfactory variety grown in California for canning and preserving, because the walls of the fruit are thick and the seed cavity is small. A limited quantity only of the fruit is dried.

Mission. The Black Mission fig, which has been grown in California since the days of the early Spanish missions, yields a dried product of black color, tender texture, and excellent flavor. The fig is not subject to souring or black smut, and the trees yield heavily. The dried product is used with the white varieties for fancy mixed packs.

Harvesting. Figs should not be picked for drying but should be allowed to ripen and partially to dry on the tree and fall to the ground of their own accord. If picked from the tree, the fruit is liable to sour on the trays or mold, and the dried product will be woody and of poor flavor. The orchard ground should be made as smooth as possible by rolling.

The fruit should be picked from the ground frequently and should not be allowed to lie on the ground more than 2 or 3 days because of danger of molding of certain varieties, toughening of the skin of other varieties, and danger of infestation with insects that gain entrance through the eye of the fig. The exception to this practice is the Kadota variety, which is picked fresh for canning, the culls used for drying.

Dipping and Sulfuring. In some dry yards Calimyrna figs are dipped in a solution of 10 lb. each of salt and hydrated lime per 100 gal. of water to remove some of the hairs from the surface, to improve the color, and to soften the skins. Some Adriatic figs are also dipped in a solution of the above or similar composition. Mission figs are not dipped before drying.

The figs are carefully sorted as they are spread on the trays, and the Adriatic figs are often, but not always, sulfured, in order to bleach the flesh and to sterilize them. It is believed that sulfuring checks fermentation and destroys insects and insect eggs. The trays are usually placed in the sulfur box in the evening and allowed to remain in the fumes of the burning sulfur overnight, 3 hr. or more sulfuring being necessary to accomplish the desired results. The Calimyrna fig should not be sulfured except under adverse drying conditions to prevent souring. The fresh Kadota figs,

mentioned above, are spread on 6- by 3-ft. wooden trays and exposed to the fumes of burning sulfur for at least 4 hr., often overnight.

Protection against Insects. Figs are subject to heavy infestation with insects. Therefore, in the better yards the figs are fumigated in small, tight rooms soon after delivery from the grove. Methyl bromide is the preferred fumigant. For protection of figs and other fruits after drying see the section at the end of this chapter.

Drying. As they arrive at the dry yard, figs are usually from one-half to two-thirds dry. On this account it is frequently possible to stack the trays immediately after fumigating and spreading the fruit and to accomplish most of the drying in the stack. Exposure to the sun toughens the skin of the Calimyrna variety, and a dried product of better quality is obtained by drying the fruit entirely in the stack.

The figs are dried until firm and until juice or sirup can no longer be expressed with the fingers.

Sorting and Boxing. The dried fruit is carefully sorted on the trays or on a broad belt to remove bird-pecked, green, and split fruit and fruit showing evidence of smut. The cull fruit is of little value except for hog feed. In some yards the Adriatic figs are dipped in salt solution after drying and are sulfured before being placed in sweatboxes. Most of the fruit is, however, placed directly into sweatboxes from the trays. Figs should not be placed in sacks, as such treatment is liable to result in crushing of the fruit and in injury to its appearance. Fumigation of the boxed fruit is advisable.

Insect Control in the Orchard. Experiments of the Fig Research Institute and of entomologists of the U.S.D.A. have shown that if the soil of the orchard is sprayed with a dilute solution of or dusted with the insecticide dieldrin and the insecticide is disked into the soil, the adults, larvae, and eggs of the beetles that infest figs are killed. The beetles spend much of their lives in the soil. Aldrin and heptachlor have also proved effective. The lethal effect of the insecticides was still evident two years after application.

Harvesting and Drying Figs in Asia Minor. Roeding has briefly described the harvesting and drying of Smyrna (Lob Injir) figs in the following manner.

Harvesting. Before harvesting begins, the orchards are weeded carefully so that the figs may be seen readily after they have dropped. The harvesting season begins about Aug. 5, but the best fruit is gathered in September.

The figs drop to the ground and are gathered in baskets holding about 50 lb. when filled, but the baskets are gathered only half full.

Dry Yard. The drying ground is usually an open space in the orchard where a few trees have died and have not been replanted. Layers of rushes, about 2 in. thick and about 3 ft. wide, with pathways between

them, are prepared. The figs are dumped from the baskets on the rushes and are then spread by hand one layer deep.

The figs are stirred daily with the hands, and the small figs, which dry first, are removed. The usual length of the drying period is 2 to 4 days.

Storing. The dried figs are usually stored in a small room in the dwelling of the owner or foreman. At the end of the season they are sorted into three grades for size and are packed in goat-hair sacks for shipment to the packing house.

None of the figs are packed in the fig-growing districts but are shipped to Smyrna and packed in special establishments for this purpose.

DATES

Dates require a hot, dry climate and an abundance of water supplied naturally or by irrigation. The Valley of the Nile, Tunisia and Algeria, and the oases of the Sahara and Arabian Deserts supply these necessary conditions and have, since the beginnings of civilization, been the world's principal source of supply of this fruit.

Varieties. California and Arizona produce all the dates grown in the United States. The principal variety is the Deglet Nur (Deglet Noor), a variety that is also grown extensively in North Africa. It is of medium size and mild flavor, and if properly cured is of light color and rather translucent. Other important varieties are the Khadrawi, from the Persian Gulf area, and the Halawi, an Arabian variety. In Egypt the Siwi and the Hayani are popular; both are soft, or invert-sugar, dates. Literally hundreds of other varieties are grown more or less commercially in the Near East.

Dates are of three types, viz. (1) dry dates, in which sucrose is the predominating sugar, (2) semidry dates, in which sucrose and invert sugars are both present in comparable degree, and (3) invert-sugar, or soft dates, in which invert sugars predominate. The Sakkoti, or bread date, of upper Egypt is an example of the first type; the Deglet Noor is probably an example of the second, the Amri of Egypt being definitely of this type; and the Khadrawi and Halawi are examples of invert-sugar, or soft, dates. The sucrose, or dry, dates of Egypt become hard and very dry on the palms before picking and are used as a staple article of diet. They are known also as "bread dates."

A very interesting variety is the Zaghloul of Egypt. It is extremely large and is eaten in the fresh state as one would eat fresh apricots or peaches. Some California growers believe that it might prove popular as a frozen-pack fresh fruit. It is quite perishable unless held in cold storage or frozen.

Harvesting. In California most of the dates ripen in the fall, the principal harvest being in October and November. The fruit is borne in large bunches on the end of a long, tough stalk hanging from the bottom of the crown leaves.

Early fall rains occur frequently enough in California to make it advisable to cover the bunches late in the summer with paper "hats" to shed rain and to exclude some dust that arises during windstorms. In humid summers or falls the bunches are sprayed with "fermate," a mold preventive. In very prolonged rainy weather, yeasts may develop and cause souring.

While the palms were still young and not very tall, picking of the dates was very simple; but many of the palms are now 50 ft. or more in height. This makes necessary the use of a tall portable picking tower or of wooden platforms attached to the trunks of the palms just below the bunches. In the Near East the pickers scale the trunks of the palms by means of a slack piece of rope around the waist and around the trunk of the palm. They climb more or less monkey-fashion in their bare feet. The bunches are then cut one by one and lowered to the ground with a small rope.

In California the dates are now picked, not by the bunch, but individually, and are placed in shallow boxes for immediate transfer to the curing and packing houses. Several pickings are made during the season.

Fumigating. In the grove ("garden") the dates become infested with insects to some extent; these would develop in storage and cause spoilage. Hence it is customary to fumigate the dates promptly after arrival at the packing house. They are placed on trays or shallow boxes in a gastight room and treated with methyl bromide gas as described in Chapter 20. Formerly carbon disulfide was used, but it is less effective than methyl bromide and is very explosive and inflammable.

Cleaning. The fumigated dates are cleaned in one of two ways. They are either passed over a shaker covered with rough toweling or between two shaker screens covered with the toweling, depending on the degree of contamination with dust; or they are brush-cleaned under fine sprays of water and drained well before traying or placing in shallow boxes for ripening or drying.

Ripening or Drying. As the dates come from the palm they contain a parchmentlike membrane, or "rag," around the pit and are often rather astringent. Consequently they are held in large rooms at a warm temperature, 90 to 95°F., for a few days, to ripen. During this period much of the cane sugar is inverted by natural enzymes to invert sugar sirup and the tannin is transformed.

The dates soften and become translucent. The rag, or seed "husk," softens or disappears sufficiently so that it is not noticeable when the date is eaten. The flavor and aroma improve greatly during ripening. Formerly

the dates were picked rather unripe and were ripened by drying at 110 to 120°F. (Fattah and Cruess, 1927). However, at present much of the crop is allowed to ripen thoroughly on the palm and can be packed without further ripening or drying in the packing house. The highest quality of fruit is handled in this manner. The dates of somewhat lower quality, generally known as dates of standard quality, undergo a series of treatments. They are fumigated on arrival, as are all dates. They are dry-cleaned with revolving brushes. They are then usually spray-washed with a detergent solution, rinsed with water sprays, dried to remove surface moisture, and sorted very critically on a slowly moving belt. Culls are discarded, and the unripe fruit goes to a ripening room. The sorted dates of this grade are usually too low in moisture content at this stage to be palatable and are next given a so-called hydrating treatment. In one large plant hydration consists in treatment in a steam cabinet, as outlined in the next section.

In Egypt, according to Brown, Bahgat, Nouty, and others,[1] the dates are allowed to partially mature on the palm and are then spread in the sun for a few days on matting made of braided palm leaves. They are then pressed into palm-leaf baskets in which they form a solid mass through expressing of sirup and its later crystallization. Insects cannot penetrate very far into this solid, semicrystalline mass. However, the finer grades of dates are ripened and handled in much the same manner as in California, the improved technique having been introduced by A. H. Nouty of the Horticulture Section of the Egyptian Department of Agriculture. In other date regions of the Near East most of the dates are handled in bulk in a manner similar to that described above for Egypt, or for export they may be packed loose without pressing.

Sorting, Grading, and Packing. The cleaned dates are carefully sorted to remove culls and to segregate them into grades. Those of normal moisture content and of fine to superfine quality are ripened as outlined above and then are packed in fancy baskets, candy boxes, or wooden veneer baskets similar to the familiar strawberry basket. A special carton with cellophane "window" is also used extensively.

In one large plant the hydrating process consists in holding the dates on trays in tight cabinets in an atmosphere of steam at about 140°F. for several hours. Too high a temperature damages quality. Other methods of hydration are also used but at present are held as trade secrets. The better ones are cooled, sorted, and packed in cartons with cellophane windows. In the latter pack the individual packages receive a few drops each of propylene oxide, a fumigant, and are then sealed. The fumigant soon vaporizes and escapes through the walls of the carton. It kills not only insect eggs but also molds and yeasts; hence dates so treated keep ex-

[1] Personal communication.

ceptionally well. E. M. Mrak and C. D. Fisher pioneered this development.

Formerly some dates were steamed and packed hot in widemouthed, flat jars or in special cans. No further sterilization was given.

Insects. In addition to infestation by the Indian-meal moth and the other common dried-fruit insects discussed in Chapter 20, dates are subject to attack on the tree by a small brown beetle (*Carpophilis dimidiatus*) that works its way under the skins at the stem end of the date and lays its eggs, which hatch into very destructive larvae (grubs). Usually fumigation at the packing house heads off this invasion before the eggs have hatched.

By-products. Dates of the lower grades, including culls of good quality, are pitted mechanically by Elliott pitters, dried bone-dry, and broken by rolls into pieces of medium size for use by bakers and candymakers. Some are pitted and ground without drying to yield a thick paste, which may be packed in parchment-lined boxes in that condition for use by bakers and others. In another process the paste is mixed with corn sirup or invert sirup and a cereal product similar to a breakfast cereal, then extruded through a "sausage spout," forming a moving cylinder, which is cut transversely into short lengths. These are coated with ground coconut or a similar product made from corn or other cereal. These "date rolls" may be used as a confection "as is" or may be coated with chocolate by candymakers. Chopped nuts are usually included in the mix. A pitter made by the Ashlock Company pits without crushing the flesh. Some dates are packed in this form, and some after pitting are cut crosswise into rings. These are used by bakers and confectioners. Table and cooking sirups can be made from dates. They have also been converted into flakes for use as a breakfast cereal. Brandy of good quality can be made from dates. It is known as "arrack" in the Near East, where it is flavored with aniseed. Other by-products are sirup, powdered dates, flakes, pitted dates stuffed with nuts or fondant, and pickled dates.

SUN DRYING OF APRICOTS

Although most of the dried apricots consumed in America are produced in California, this fruit is also dried commercially in France, Australia, and Asia Minor. It has been an important article of diet in Asia Minor for many centuries.

Varieties. In California the Royal, Blenheim, Tilton, and Moorpark are the principal varieties used for drying. The Hemskirk and Peach varieties are grown in limited quantities only. The above varieties are described in Chapter 8.

In the coast counties of central California (Santa Clara, Alameda, Napa, San Benito, and Sonoma Counties), the Blenheim is preferred to all other

varieties. In southern California and in the hot interior valleys, the Royal is the principal variety used for drying but the Tilton is also popular.

Harvesting. The fruit should be allowed to remain on the trees until "eating ripe," i.e., somewhat riper than for canning purposes. Apricots should be picked frequently, so that the fruit shall be neither too ripe nor too green. Underripe fruit yields a badly shriveled, tough, dried product of poor flavor, and overripe fruit forms slabs during drying. Slabs, while of excellent flavor and color, are of unattractive form and must be sold at a low price.

Cutting and Traying. The fruit in the lug box is placed beside the cutter on a level with the tray, or part of the box may be dumped on the tray. Fruit and empty trays are brought to the cutters, and filled trays are removed, by men or boys assigned to these duties. Cutting is also done from a slowly moving, broad belt on to slowly moving trays. The cutters' only duties are to cut the fruit in half around the suture, remove the pits, and spread the cut halves on the trays with cups upward. The knife should be run completely around the fruit to the pit, in order to give smooth edges to the cut fruit. Cutters average from 600 to 1,200 lb. per day. A mechanical pitter has been made recently that will cut several tons of fruit per hour. Also, the small power-driven pitter used in canneries is employed in some dry yards.

In most yards trays are 8 by 3 ft. in size, and the fruit is spread one layer deep. Each square foot of tray surface will hold about 2 lb. of cut fruit.

The pits are placed in lug boxes and are later spread on a concrete slab or on trays and dried in the sun for sale to by-product factories.

Sulfuring. The filled trays are stacked on dry-yard cars and placed in a sulfur box, where the fruit is exposed to the fumes of burning sulfur at least 3 hr. The last cars to enter the sulfur houses in the afternoon remain overnight. The fruit should be sulfured until the cups fill with juice or until the flesh is permeated with sulfur dioxide, as shown by the change in color and texture of the flesh examined, when several halves are cut in two.

Approximately 5 to 8 lb. of sulfur per ton of fruit is normally required. However, the length of exposure to the fumes and the concentration of sulfur dioxide in the fumes are far more important than the weight of sulfur used.

Properly sulfured apricots should not turn brown during or after drying and should retain the clear golden yellow of the fresh fruit. Sulfuring does not bleach the carotene pigment of the apricot but merely prevents darkening of other pigments.

Drying. The apricot ripens in July and early August in California, i.e., in midsummer; consequently no difficulty is experienced in obtaining sufficient sunshine for drying the fruit.

The trays are spread in the sun for 1 to 4 days, which intensifies the golden color of the fruit and changes green fruit to a golden-yellow color, in addition to causing drying.

When the fruit is one-half to two-thirds dry, the trays are stacked in such a manner that the prevailing wind may pass freely between them.

Properly dried apricots should be soft and pliable but not sticky, and when a handful of the fruit is squeezed, it should not stick together when the pressure is released. When an individual piece is pressed between the fingers, it should not be possible to obtain juice or sirup. On the other hand, the fruit must not be overdried. It should contain about 18 per cent moisture.

Sorting, Boxing, and Sweating. When most of the fruit is sufficiently dry, it is carefully sorted, slabs being placed in a separate box. Fruit that requires further drying is returned to the trays, and the properly dried fruit is scraped from the trays with wooden paddles or steel scrapers into lug boxes.

The dried apricots are stored in bins or in heaps on a wooden or concrete floor to undergo sweating for several weeks before packing or delivery to the packing house. Boxes are usually employed as containers for delivery of the fruit. Storage at 32 to 40°F. in lug boxes is to be preferred to room-temperature storage, since it excludes rodents and prevents the growth of insects. Also, it retains color and flavor.

Yields. The usual drying ratio is about 5:1, but will vary with variety and maturity. The yield of dried, unpitted whole apricots is higher, about 4:1.

Unpitted Dried Apricots. Occasionally very small apricots are dried whole without cutting in half or pitting. The fruit is first dipped in lye as described elsewhere for prunes, then sulfured 6 to 10 hr., and dried in the sun in the usual manner. The product is satisfactory for preparing and serving in the same manner as dried prunes, but the market is limited. In some dry yards the half-dry fruit is pitted by slipping out the pits with the fingers.

Apricot "Leather." In Asia Minor ripe apricot pulp is dried on smooth boards in the sun to a leathery consistency in the form of sheets, which are then rolled for convenience in packing. The "leather" is eaten as a confection or is cooked in the form of a sauce.

SUN DRYING OF PEACHES

Most of the sun-dried peaches of California were formerly sold through a cooperative association known as the California Peach and Fig Growers' Association, under the Blue Ribbon brand, but at present most of the dried fruit is packed by independent packers and by the California Prune and Apricot Growers' Association.

Australia and South Africa are increasing their output of sun-dried peaches and are following California methods of drying and marketing.

Varieties. A peach suitable for sun drying should be a freestone variety of large size and high sugar content. It should be pulpy rather than juicy, with flesh of rich golden-yellow color and of pleasing flavor.

The Muir peach most nearly fulfills these requirements, and more than 60 per cent of the dried fruit produced in California is of this variety. The Lovell is second in importance to the Muir. Other important varieties are the Rio Oso Gem, Crawford, Foster, Salway, and Elberta. One of the principal objections to the Elberta is the red color of the pit cavity.

Clingstone varieties cannot be pitted economically and give a low yield of dried product because of their low sugar content. Nevertheless, considerable quantities were dried in dehydraters during the Second World War.

Harvesting. Peaches should be picked when they have become slightly soft to the touch over the entire surface. They are firmer than apricots, but when bruised even slightly, the flesh darkens quickly. They must therefore be handled with great care and should be cut and spread on trays as soon after picking as possible.

Several pickings should be made during the season in order to ensure a dried product of highest quality. Although much of the fruit is knocked with poles or shaken from the trees, this method should not be used, because it not only results in bruising the fruit but removes a large proportion of green fruit, which gives a dried product of unattractive gray color, poor flavor, and woody texture.

Insect Infestation. Peaches are subject to severe damage by insects. See Chapter 20 for control measures.

Cutting, Traying, and Sulfuring. The cutting and traying operations are conducted as described elsewhere for apricots, the cost of pitting being less because of the larger size of the fruit. A small pitting machine run by a single operator can also be used. The halves are placed with cups upward on trays 8 by 3 or 6 by 3 ft. in size.

Peaches are sulfured 4 to 6 hr. or overnight. A longer period of sulfuring is required than for apricots because of the larger size of the halves.

Clingstone peaches are usually pitted and lye-peeled as for canning. However, some of the halved peaches are dried without peeling. They must be sulfured at least 5 hr. and are usually dehydrated instead of sun-dried.

Drying and Sweating. The method of drying is identical with that described elsewhere for apricots, although the drying period is somewhat longer. As much of the drying should take place after stacking as possible, in order to obtain a dried product of highest quality.

A well-dried peach should be golden yellow, not gray-green or brown, and firm and pliable but not sirupy or sticky.

The fruit is sorted on the trays after drying and placed in sweatboxes, in bins, or in piles on the floor to undergo sweating before delivery to the packing house. The fruit continues to lose moisture during this storage period.

The usual drying ratio is about 4.5:1 but will vary from 3.5:1 to 7:1 according to the variety and its maturity. The Muir and Lovell varieties yield more heavily than the Elberta.

SUN DRYING OF PEARS

The Bartlett pear is the most important variety grown commercially for sun drying, but dried pears are very much less important than dried apricots, prunes, figs, and raisins.

In most pear-growing sections of California the pears used for drying are the culls from fresh-fruit packing houses and canneries. In Lake County in California, however, because of lack of transportation facilities a large proportion of the entire crop is utilized for drying.

Harvesting. Bartlett pears are harvested while still too green for eating and are allowed to ripen after picking. If to be used for drying and not for fresh shipment, the fruit should show beneath the background of green a faint to pronounced yellow color but should still be too firm for eating fresh.

Ripening and Sorting. Cull pears are usually placed in lug boxes to ripen or on straw in rows about 1 ft. wide and 6 in. deep and are covered with straw. As the fruit ripens it is sorted two or three times. Usually a week to 10 days is required for ripening, although wormy and sun-burned fruit will ripen in less time.

In Lake County the fruit is allowed to ripen in lug boxes stored beneath a shed and is sorted frequently in order to obtain prime ripe fruit.

The loss in sorting amounts to 3 to 25 per cent, depending upon the quality of the fresh fruit and frequency of sorting.

In some of the large dry yards the pears are graded for size by a mechanical grader before ripening. Large pears require a longer period of drying than small ones; hence the desirability of placing on each tray fruit of uniform size.

Treatment to Remove Spray Residue. Bartlett pears are heavily sprayed several times during the spring and summer; consequently they carry considerable poisonous spray residue (lead arsenate or DDT), which must be removed before the fruit is cut and dried. This is accomplished by passing it through a tank of dilute hydrochloric acid, about 0.5 to 1.0 per cent of the acid, for 1 to 3 min., and rinsing in water, or by applying the acid solution and water by pump-driven sprays to remove lead arsenate. DDT usually disappears before the fruit is picked. The Entomology

Department of the University of California can supply information on its removal.

Cutting and Traying. The pears are cut when they have become "eating-ripe," but before they have become mushy. Overripe fruit produces slabs, whereas underripe gives a dried product of woody texture and poor flavor.

The fruit is cut in half lengthwise but is not peeled. The pears are usually cut by hand, but a machine is available. In most dry yards the stem and calyx are removed, but the fruit is not cored.

The pears are spread with the cut surface upward on trays 8 by 3 ft. in size.

Sulfuring. The fruit and trays should be thoroughly sprinkled with water before they enter the sulfur house, in order to facilitate absorption of the sulfur dioxide. In some yards the cut fruit is dipped in or sprinkled with dilute brine, as salt retards darkening.

In Sacramento and Contra Costa Counties, where cull pears are used, the fruit is sulfured from 8 to 24 hr. and in Lake County 48 to 72 hr., the sulfur being replenished at about 8-hr. intervals. Data taken by the University of California Food Technology Department Laboratory indicate that with tight sulfur houses the time can be greatly shortened. A pear properly sulfured before drying is very soft throughout, since sulfuring softens the tissue very markedly. The market demands a dried pear that is very light in color and nearly transparent, a condition that can only be obtained by the excessively long periods of sulfuring noted above.

Drying. In the method used in Lake County, the pears are spread in the sun for from ½ to 2 days. The trays are then stacked beneath long sheds open at the sides and so placed that air may circulate freely between the trays. Three to six weeks' time is required to complete the drying process, the slow drying in the shade in this manner producing a dried pear that is nearly transparent and very attractive in appearance.

In the Contra Costa County process the pears are spread in the sun until one-third to two-thirds dry before the trays are stacked. Drying is accomplished in a shorter time than in the Lake County process, but the dried product is less translucent and is of darker color.

Because of heavy sulfuring, dried pears do not undergo molding or fermentation readily and need not be dried to so low a moisture content as peaches or apricots before removal from the trays. A properly sun-dried pear should be pliable, of tender texture, light color, and translucent. A chalky-white or brown color is not desired by the trade.

Walnuts. Walnuts are harvested by shaking or knocking the matured nuts from the trees, followed by picking them from the ground by hand or by special machine. The outer hull, or husk, is still adhering to most of the nuts. This is removed in hullers consisting of revolving, stiff-wire brushes operating inside a special housing and heavy sprays of water.

Thus the nuts are hulled and washed in a single machine. The hulled nuts are sorted to remove culls and "sticktights."

Until about twenty-five years ago most of the walnut crop was dried in the sun, but at present dehydration has almost completely replaced sun drying of the nuts. However, many small orchards still sun-dry their crops. If the nuts are left on the trees for a few days beyond the usual harvesting date, the hulls crack open on most of the nuts and are then easily removed by hand hulling, if the small grower does not have access to a mechanical huller.

The usual sun-drying tray for walnuts is 6 by 3 ft. in size and about 4 in. deep, the sides being of 1 by 6 material. The bottoms are usually made of narrow wooden slats. The author's sun-drying trays are made of 1 by 4 redwood boards for the frame, and the tray bottoms consist of wire netting of small mesh (so-called chicken netting) that will retain the smallest nuts. The screen or netting permits good ventilation and promotes rapid drying.

The washed and hulled nuts are spread on the trays one layer deep, and the trays placed in the sun. The nuts should be stirred at least once a day during drying. They must be covered at night in order to prevent wetting by dew, because if this should occur many of the nuts will crack open along the suture when the sun strikes them the following morning. The trays may be stacked at the end of the day, and a canvas or other tight cover placed over the stack. When the nuts have become nearly dry the trays may be left in the stack for 2 or 3 days for drying to be completed. The slower drying in the stack at this stage will minimize loss by splitting. The final moisture content of the nuts should be 10 per cent or less.

MISCELLANEOUS FRUITS

Cherries. Split, overripe, and rain-damaged cherries are dried in the sun to a limited extent in California.

Preparation of cherries for sun drying consists in dipping the fruit in a boiling dilute lye or sodium carbonate solution to check the skins. White cherries, such as the Royal Anne, are improved in appearance if sulfured for about 1 hr. after lye dipping. Black varieties need not be sulfured. Drying is conducted as described elsewhere for prunes.

Berries. Raspberries, strawberries, and loganberries are frequently sun-dried for home use. The untreated fruit is spread on wooden trays in the sun until about two-thirds dry. Drying is then completed after stacking the trays. L. C. Barnard of the University of California has found a dried product of improved color, and flavor is obtained if the fresh berries are sulfured for about 1 hr. before drying.

All berries are of much more attractive appearance and better cooking quality if dehydrated.

Persimmons. The Japanese dry large quantities of persimmons, which are used as a confection and food. The ripe fruit is peeled and threaded on strings which are hung in the shade until the fruit is dry. The fruit must not be sulfured or it will remain astringent.

Protection of Drying Fruit from Insect Damage. Fruits exposed on trays, either in the open or when stacked, are subject to insect attack. Insects may lay their eggs on the drying fruit. These eggs hatch, and the resulting larvae may greatly damage the fruit by eating it and marring its appearance by webbing. The Federal Food and Drug Administration has established maximum tolerances for insect infestation in dried fruits and in fig paste.

The raisin moth (*Ephestia figulella* Gregson) is particularly obnoxious. It multiplies early in the summer in mulberries that have fallen from the trees and dried. Such trees near dry yards should be eliminated. The Indian-meal moth (*Plodia interpunctella*) is also a serious dried-fruit pest, but in packing houses rather than in dry yards.

It has been shown by Simmons and associates of the U.S.D.A. at Fresno, California, that cut fruits can be protected very effectively against dry-yard insect infestation by covering the fruit and trays with tobacco shade cloth after the trays have been stacked.

Sweatboxes of raisins were also protected in a similar manner satisfactorily. Raisins in uncovered boxes in one test by Simmons and others showed many more insects per ton than the covered raisins.

Elimination of all waste fruits from the fields and orchards is very desirable, since such removal robs the insects of material in which to propagate.

The raisin moth infests the fruit principally after the trays have been stacked.

Farm Storage. Simmons and associates recommend that any dried fruit to be held in storage be fumigated at once. Fumigable storage rooms are highly desirable, as they permit refumigation of the fruit at intervals. The storage room should be screened and rendered as nearly insectproof and rodent proof as possible.

The dried-fruit beetle (*Carpophilus hemipterus* L.) infests figs during drying and storage. It breeds prolifically in piles of discarded grape pomace or in souring fruit wastes of any kind. The insects travel several miles from their breeding places and thus may infest fruit over a large area from a single focus. Fumigation of the figs as soon as gathered is one protective measure; another is elimination of waste fruits used as breeding places by the insects.

Formerly carbon disulfide was generally used as a dried-fruit fumigant;

later hydrogen cyanide gas was used. The former is very explosive, and the latter is poisonous to man, hence extremely dangerous to use in farm dried-fruit storage rooms. It has been found that the fruit retains an appreciable amount of hydrogen cyanide fumigant.

Ethylene oxide may be used with greater safety than carbon disulfide or hydrogen cyanide. Nichols suggests 4 lb. per 1,000 cu. ft. of room space if the room is not exceedingly tight, and 2 lb. if the room is practically leakproof. Chloropicrin, tear gas, used at the same dosages as the ethylene oxide, is also effective, although it must be handled with greater care as it is very irritating to workmen and animals. The fumigation should last 8 to 24 hr.

Ethylene dichloride and carbon tetrachloride mixture, 3 of the former to 1 of the latter, is also used. The dosage is 15 to 20 lb. per 1,000 cu. ft. It is not explosive at concentrations used and is not irritating to the mucous membrane. It has an anesthetic effect on man similar to that of chloroform. Methyl bromide is very effective, but is too toxic to man for safe use on the farm except by experienced operators. It is probably the most effective of the commonly used fumigants.

Fly sprays should never be used near or on dried fruits as they leave disagreeable odors and flavors.

Figs should be fumigated not only before but also after drying. See also Chapter 20 on fumigation of dried fruits at the packing house.

Laboratory Examination. Chapter 20, Packing of Dried Fruits and Vegetables, gives information on this subject.

REFERENCES

Batchelor, L. D., Christie, A. W., Guthier, E. H., and Larue, R. G.: Sun drying and dehydration of walnuts, *Univ. Calif. Agr. Expt. Sta. Bull.* 376, 1924.

Bioletti, F. T.: Relation of maturity of grapes to the quantity and quality of the raisins, *Proc. Intern. Cong. Viticulture*, 1915.

Cruess, W. V.: Salvaging rain damaged prunes, *Univ. Calif. Agr. Expt. Sta. Circ.* 212, 1919.

——— and Fattah, M. T.: Factors affecting the composition of dates, *Plant Physiol.*, **2**(3), 349–355, 1927.

De Ong, E. R.: Prevention and control of insects in dried fruits, *Calif. Dept. Agr. Monthly Bull.*, 1921, pp. 72–74.

Fisher, C. D., Mrak, E. M., and Long, J. D.: Retention of sulfur dioxide by fruits during drying, *Fruit Products J.*, **21**(6–8), 175–177, 199–200, 217, 219, 237–238, February–April, 1942.

Howard, B. J.: Fig testing, *U.S. Dept. Agr., Food Drug Insecticide Admin., Circ.*, 1929. Insect infestation. Mimeographed.

Jacob, H. E.: Relation of maturity to yield and quality of raisins, *Hilgardia*, **14**(6), 321–345, 1942.

Journals:

California Cultivator, Los Angeles, now combined with *California Farmer*, San Francisco.

Pacific Rural Press, San Francisco, Calif., now *California Farmer*, San Francisco.

The Sunsweet Standard, California Prune and Apricot Growers Association, San Jose, Calif.

The Western Canner and Packer, San Francisco, Calif.

Linsley, E. G., and Michelbacher, A. E.: Insects affecting stored food products, *Univ. Calif. Agr. Expt. Sta. Bull.* 676, March, 1943.

Long, J. D., Mrak, E. M., and Fisher, C. D.: Investigations on the sulfuring of fruits for drying, *Univ. Calif. Agr. Expt. Sta. Bull.* 636, July, 1940.

Mason, S. C.: Date culture, *U.S. Dept. Agr. Bull.* 1457, 1927.

McCutcheon, W.: Drying racks for Sultanas, *Misc. Pub.* 2960, March, 1934, Government Printer, Sydney, Australia.

Meyers, J. G.: Report on insect infestation of dried fruit, *Empire Marketing Bd. Pub.* 12, November, 1928. Obtainable from H.M. Stationery Office, London.

Michelbacher, A. E., and Ernst, F. H.: The storage and protection of dried food products, *Univ. Calif. Agr. Ext. Serv. Circ.*, 1943.

Mrak, E. M., Fisher, C. D., and Bornstein, B.: Effect of certain substances and pretreatments on retention of color and sulfur dioxide by dried cut fruits, *Fruit Products J.*, **21**(10), 297–299, June, 1942.

——— and Phaff, H. J.: Sun drying of fruits, *Univ. Calif. Agr. Expt. Sta. Circ.* 392, 1949.

Parker, W. B.: Control of dried fruit insects in California, *U.S. Dept. Agr. Bull.* 235, 1915.

Phaff, H. J., and Mrak, E. M.: Sulfur house operation, *Univ. Calif. Agr. Expt. Sta. Circ.* 382, April, 1948.

Popenoe, P. B.: "Date Growing," published by the author, Los Angeles, 1913.

Quinn, George: Fruit drying for amateurs and beginners, *South Australia Dept. Agr. Bull.* 198, 1935. See also *New South Wales Dept. Agr. Bull.* 52, 5th ed., 1920.

Robinson, R. H., and Hatch, M. B.: The removal of lead and arsenic spray residues from pears, *Ore. Agr. Expt. Sta. Bull.* 317, 1933.

Showell, H.: Grape drying practise in Australia, *J. Dept. Agr. South Australia*, **35**(5), 557–567, December, 1931.

Simmons, P., Barnes, D. F., Donohoe, H. C., and Fisher, C. K.: Progress in dried fruit investigations, report, *U.S. Dept. Agr., Bur. Entomol., Dried Fruit Insects Lab., Rept.*, 1935. Mimeographed.

Vaughn, R. H., and Mrak, E. M.: Keep your fruit clean, *Univ. Calif. Agr. Expt. Sta. Circ.*, May, 1954.

von Loesecke, H.: "Drying and Dehydration of Foods," Reinhold Publishing Corporation, New York, 1943.

CHAPTER 18

DEHYDRATION OF FRUITS

Just as the Civil War stimulated the canning industry, the Boer War and the First World War stimulated the dehydration industry. To conserve cargo space and transportation facilities, enormous quantities of foods were dehydrated during both world wars and shipped to the Allied armies in Europe.

In Germany in 1898 there were, according to Prescott, only three drying plants. In 1917 the number had increased to about 1900, a fact that explains in part Germany's ability to maintain her food supply during the war. Similar expansion occurred from 1939 to 1944.

The dehydration of fruits has become a well-established and growing industry. Apples have been dehydrated (or evaporated) in America for at least a century, and the dehydration of prunes in the Pacific Northwest is an old and formerly very important industry.

Definitions. Dehydration is at present defined industrially as drying by artificially produced heat under carefully controlled conditions of temperature, humidity, and air flow. To dehydrate means to remove water.

The term "dried" is applied to all dried products, regardless of the method of drying.

Evaporation is usually considered industrially to mean drying under conditions of humidity, temperature, and air flow not so carefully controlled as in dehydration. Evaporation is a broader term than dehydration. If applied literally, the evaporation of fruit would mean the complete vaporization of the whole fruit, both water and solids. Alcohol, ether, and other liquids, as well as water, may be evaporated.

Desiccation is essentially equivalent in meaning to dehydration.

The terms "drier," "dehydrater," and "evaporator" are at present used more or less indiscriminately, although the term "drier" is often considered to be a general one applicable to all types of drying apparatus and a dehydrater is often considered to be more efficient and to permit of more exact regulation than an evaporator.

Relative Merits of Sun Drying and Dehydration. At the present time most dried fruit, other than prunes, is dried in the sun by the methods described in Chapter 17, but dehydration is rapidly increasing in impor-

tance because of its following advantages: (1) dehydrated fruits, when cooked, more nearly resemble the cooked fresh fruit in flavor and color than do cooked sun-dried fruits; (2) they are generally produced under more sanitary conditions than sun-dried fruits; (3) dehydration permits of more careful control of the quality of the finished product; (4) less land and fewer trays are required for dehydration than for sun drying; (5) in seasons of early rains, the use of dehydraters prevents loss through rain damage.

Relative Cost. Dehydration has usually been somewhat more costly than sun drying, but undoubtedly the superior cooking quality of the dehydrated products will cause them to command a sufficiently higher price to more than counterbalance the slightly greater cost of production.

Relative Yields. Dehydration usually gives a somewhat higher yield of dried product (calculated to a common moisture content) than is obtained by sun drying, even under ideal sun-drying conditions. This difference is due probably to loss of sugar in sun drying through respiration or fermentation. During cloudy or rainy weather loss of sugar in sun drying through fermentation becomes excessive.

For the small orchardist the cost of sun-drying trays is usually less than that of a dehydrater, but for the large operator the cost of the dehydrater may in some cases be no more than that of sun-drying trays. Costs of construction will be discussed in greater detail later in this chapter.

Color. During sun drying of green or slightly immature cut fruits, such as peaches and apricots, the fruit acquires the color of the fully mature fruit. In dehydration the fruit retains the color possessed at the time of cutting, fruit of green color retaining this color after dehydration. Therefore it is essential that fruit used for dehydration be fully mature. If the cut fruit is exposed to the sun for a few hours before dehydration, the green color disappears.

Cooking Quality. The dehydrated fruits in all cases are superior to the sun-dried for cooking purposes, although not always equal to or superior in appearance before cooking. Comparison should be made of the refreshed and cooked fruits rather than the dried fruits.

PRINCIPLES OF DEHYDRATION

A thorough knowledge of dehydration is not possible without an understanding of the fundamental physical and chemical principles involved.

Advantages of Air as a Drying Medium. Foods may be dried (1) in air, (2) in superheated steam, (3) *in vacuo*, (4) in inert gases, or (5) by direct application of heat. Air, however, is the usual medium employed industrially for the following reasons: It is less costly and more convenient to install and operate dehydraters using air as a drying medium; where air is used, overheating is avoided; air can be used to conduct heat to the product

to be dried and to conduct the liberated moisture from the product undergoing drying; no elaborate or costly moisture condensers are required when air is used as the drying medium; the use of air permits gradual drying and thus avoids loss of juice by dripping; air also reduces the tendency for fruits to discolor and scorch.

Functions of Air in Drying. Air has two principal functions in the drying of fruits or other foods. It conveys heat from the furnace room or other heating device to the product and thereby causes the water in the product to vaporize, and it also serves as a vehicle for the transfer of moisture to the outside atmosphere. Both functions are important and necessary.

Relative Volumes of Air for Heat Conductance and Transportation of Water Vapor. A larger volume of air is required to conduct heat to the drying chamber than to transport water vapor from the drying chamber, as illustrated in the following discussion.

For example, if dry air enters the drying chamber at 150°F. and leaves at 110°F. (a drop of 40°F.), approximately 1,750 cu. ft. of air is required to furnish enough heat to evaporate 1 lb. of water, while at 110°F. only approximately 235 cu. ft. of air (dry on entry to the dehydrater) is required to transport 1 lb. of water vapor. The ratio of air required to supply heat to the air required to remove liberated moisture is in this case about 7:1. If, however, the entering air is not perfectly dry or if the escaping air is not saturated, the ratio becomes lower.

Since more air is required for transportation of heat than for transportation of moisture, the former amount must be used in calculating the air requirements of a given dehydrater.

For simplicity, the above calculations disregard the slight differences in volume of air caused by differences in temperature, also the slight differences in the specific heat of air occasioned by differences in relative humidity. Increase in temperature increases the volume of air in accordance with the law of Gay-Lussac; i.e.,

$$V = V_0(1 + 0.003665t)$$

where V = volume at temperature (t), and V_0 = volume at 0°. The formula is based on centigrade temperature.

Expressed in a different manner, the volume of any gas maintained at constant pressure increases $\frac{1}{273}$ in volume for each 1°C. rise in temperature. For this reason it is often convenient to express air measurements in terms of weight, e.g., as kilograms or pounds. When desired, these may be converted into cubic meters or cubic feet.

Necessity of Heat. It should be borne in mind that it is heat which produces evaporation and not the air or any mysterious property assigned to a vacuum. Approximately 1000 B.t.u. of heat is required to change 1 lb. of water to vapor, and this figure is known as the "latent heat of vaporiza-

tion of water." The latent heat of vaporization will vary somewhat with the temperature at which evaporation occurs, but at the temperatures used in the drying of fruits and vegetables an average of about 1000 B.t.u. may be taken for purposes of calculation of air requirements, etc. A British thermal unit (1 B.t.u.) is the amount of heat required to raise the temperature of 1 lb. of water 1°F. Table 30 gives the relation of temperature of evaporation to heat required for the evaporation of 1 lb. of water.

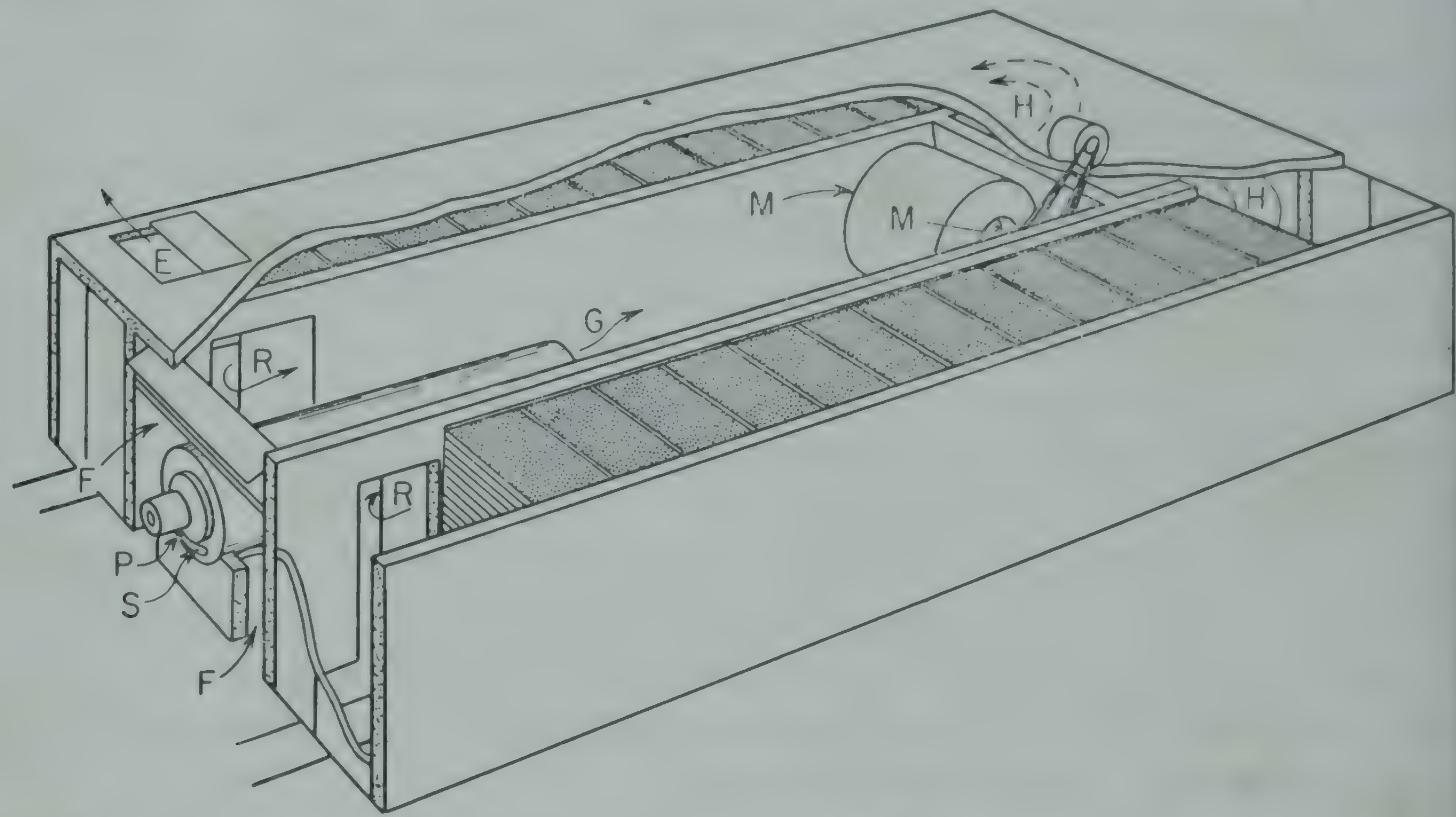


FIG. 88. Double-tunnel, counterflow, direct-oil-fired dehydrater with centrifugal fan: *E*, exhaust air; *F*, fresh air; *G*, gases heated in furnace; *H*, hot air delivered by fan to tunnels; *M*, mixture of fresh air, air heated in furnace, and recirculated air entering the fan; *P*, primary fresh air for initiating combustion in the furnace; *R*, recirculated air; *S*, secondary fresh air for completing combustion in the furnace. (*After Perry, Mrak, Phaff, Marsh, and Fisher.*)

These amounts are required regardless of whether the product from which the water is evaporated undergoes boiling. The mere fact that heat is conducted to the product by air, and that evaporation of the moisture from the product occurs without boiling, does not alter the amount of heat required for evaporation.

It is possible to dry fruit or other materials with air at atmospheric temperatures without previously heating the air. In this case the air will drop in temperature, and if this fact and the weight of the air are taken into account, it will be found that the evaporation process has taken the normal number of heat units and that the air possesses no miraculous power of "absorbing" moisture without the use of heat. Heat in this case comes from solar energy, since the atmospheric air has been heated by the sun's rays.

Volume of Air Required. The volume of air required for the evaporation of 1 lb. of water will vary greatly with the temperature at which evapora-

tion takes place, owing to expansion in volume with increase in temperature. The calculations are greatly simplified, however, if they are based upon the weight of the air and only the final results are expressed in volume. In most dehydraters all the heat required for the evaporation of moisture is obtained from heated air, the work done in evaporating moisture causing a drop in temperature of the air. This drop is a function of the amount of moisture evaporated and can be calculated if the other conditions are known.

Ridley has calculated the air requirements for a typical tunnel air-blast dehydrater as follows:

One cubic foot of air at 60°F. requires 0.01807 B.t.u. to increase its temperature 1°F., and conversely 1 cu. ft. of air dropping 1°F. will release 0.01807 B.t.u. of heat.

Condition in Tunnel Drier. If we assume a condition in which the air enters the dehydrater at 60°F. and is heated to 160°F., at which temperature it enters the tunnel, and is exhausted from the dehydrater at 120°F., the temperature drop will be 40°F.

The heat required to evaporate 1 lb. of water at 60°F. is 1058 B.t.u., and the heat required to heat 1 lb. of water from 60 to 160°F. and evaporate this amount of water at the higher temperature is 1102 B.t.u., the heat units necessary decreasing with rise in temperature. Assuming a mean value of 1080 B.t.u., the number of cubic feet of air required will be 1,080/0.01807, or approximately 60,000 cu. ft. dropping 1°F., equivalent to 1,080/0.01807 ÷ 40, or 1,500 cu. ft. of air dropping 40°F. This is assuming that the air is measured at 60°F. If it is measured at 160°F., a much larger volume is required because of the expansion of the air through rise in temperature. Thus 1,500 cu. ft. at 60°F. becomes 1,805 cu. ft. at 160°F. The volume at any other temperature can be calculated by Gay-Lussac's law.

In addition to the heat required for the evaporation of water, heat is required for heating the trays, cars, and tunnel walls to the temperatures used during drying.

Air Requirements for Prunes. Assuming that the dehydrater holds 10 tons of fruit, that it is desired that the fruit be dried in 24 hr. under the temperature conditions noted above, and that the drying ratio of the fruit is 2½:1 (that is, 2½ lb. of fresh fruit yields 1 lb. dry), the amount of moisture to remove per 24 hr. is 12,000 lb., or 8.3 lb. per min. With a temperature drop of 40°F., there will be required 8.3 × 1,500, or 12,450 cu. ft. per min. This is a minimum requirement and does not take into account losses of heat by radiation and leakage and that required to heat the cars, trays, etc., to the temperature of the dehydrater. Experience has proved that this quantity should be increased in actual commercial practice to at least 15,000 cu. ft. per min., and preferably to 20,000 cu. ft. per min., in order to dry the fruit in the required time of 24 hr.

Other Fruits. Apples, peaches, apricots, and most other fruits possess drying ratios of 5:1 or 6:1. Therefore the air requirements will be considerably larger for these other fruits than for prunes. With a drying ratio for apples of 6:1 and a drying time of 10 hr., it would be necessary to remove 16,666 lb. of water per 10 hr., or 27.7 lb. per min. This would require, with a temperature drop of 40°F., not less than 41,500 cu. ft. per min. In a similar manner the air requirements for other fruits or for other temperature conditions can be calculated.

Air Velocity. In dehydraters tested in California in 1920 and 1921, and in 1941 to 1945, it was found that the air velocity varied from less than 20 to nearly 1,000 ft. per min. The velocity was measured by means of an anemometer, an instrument equipped with a small disk-type fan, as shown in Figure 89.

Air velocity can also be determined from measurement of the air pressure in the drying compartment by means of a Pitot tube. A description of this instrument will be found in this chapter in the section on air pressure.

Velocity Equation. It has been found that the rate of evaporation of water from a free surface is directly proportional to the velocity of the air, other things being equal. This relation may be expressed by the following equation (according to Carrier):

$$W = 0.093 \left(1 + \frac{v}{230}\right) (e' - e)$$

where W = pounds evaporated per square foot per hour, v = velocity of air over surface in feet per minute, e' = vapor pressure of water corresponding to its temperature, and e = vapor pressure in the surrounding atmosphere.

Thus at an air velocity of 230 ft. per min., drying is twice as rapid as in still air, and at 460 ft. per min. it is three times as fast as in still air.

Velocity in Commercial Dehydraters. In practice it has been found by observation that velocities above 300 and not in excess of 1,000 ft. per min. should be used in air-blast dehydraters. At velocities above 1,000 ft. per min., static pressure and the power necessary to operate the fan become so great that additional increase in velocity is apt to become uneconomical. It is also true that evaporation from the surface of fruits and vegetables is slower than from a free surface, such as a wet lampwick, and that the Carrier equation does not apply well in high air velocities.

Perry et al. (1946) state that air velocity has less effect on the drying rate of slowly drying fruits, such as prunes and pears, than upon that of rapidly drying material, such as diced vegetables or sliced apples. For example, taking the rate of drying as 1.00 at an air velocity of 600 ft. per min., the relative rates at several other velocities for prunes and for diced vegetables are as shown in Table 36.

TABLE 36. EFFECT OF AIR VELOCITY ON DRYING RATE OF PRUNES

Velocity, ft. per min.	Relative drying rate for prunes	Relative drying rate for diced vegetables
300	0.87	0.70
400	0.92	0.80
500	0.97	0.90
600	1.00	1.00
800	1.06	1.15
1,000	1.11	1.30

SOURCE: After Perry et al.

Small pieces dry more rapidly than large ones, because the volume is smaller in proportion to the surface and because the moisture within the piece has a shorter distance to travel in order to reach the surface.

The velocity of air required will vary with the distance between trays and the load on the trays. A convenient way of expressing air requirements for dehydraters is in terms of cubic feet of air per minute per square foot of

TABLE 37. EXAMPLES OF AIR-FLOW MEASUREMENTS AND DRYING TIMES

Plant	Type of dehydrater	Fruit	Velocity of air across trays, lin. ft. per min.	Total volume of air, cu. ft. per min.	Volume of air per 100 sq. ft. of tray surface, cu. ft. per min.	Approximate drying time, hr.
F	Air-blast direct heat.	Grapes	424	20,800	290	24
C	Air-blast direct heat.	Grapes	485	15,800	275	24
A	Air-blast direct heat.	Prunes	510	44,000	255	24
O	Air-blast tunnel, batch-type.	Grapes	450	17,500	250	18–24
E	Air-blast tunnel type. . . .	Grapes	265	8,600	250	18–30
G	Air-blast direct heat.	Grapes	197	7,486	235	22
B	Air-blast tunnel type. . . .	Prunes	357	11,390	200	30
M	Stack-type gravity air flow.	Prunes	Less than 20	4,500	130	30
M	Stack-type gravity air flow.	Prunes	Less than 20	4,800	100	36
N	Ceramic oven.	Grapes	Less than 20	6,017	110	60

SOURCE: After Cruess and Christie.

tray surface. For an air-blast dehydrater, this number should not be less than 250 cu. ft. per 100 sq. ft. of drying surface.

Measurements of air velocity and drying times for various fruits, obtained in the study of dehydraters in California, are given in Table 37 (compare F and N particularly).

Effect of Humidity and Temperature. Tiemann is his bulletin on the theory of drying gives the relation between the temperatures and humidities of the ingoing and outgoing air, the volume of air required, and the heat units required to evaporate 1 lb. of water.

Perry et al. (1946) state that the rate of drying depends upon the temperature of the fruit, but since this cannot be measured readily under commercial operating conditions, it is more convenient to refer to the temperature of the air passing around the fruit. For prunes, a slow-drying fruit, they give the following relative rates of drying at several temperatures of the air adjacent to the fruit:

Temperature, °F.	*Relative drying rate*
150	0.68
155	0.78
160	0.89
165	1.00
170	1.12

The drying rates, according to Perry et al., are roughly proportional to the fourth power of the Fahrenheit temperature.

In respect to the effect of relative humidity of the air used in drying, they state that for rapidly drying materials such as diced vegetables, the rate is roughly proportional to the wet-bulb depression (dry-bulb–wet-bulb temperature difference); but that for prunes the rate of drying is practically independent of the wet-bulb temperature if the relative humidity is not above 40 per cent. At 60 per cent relative humidity the rate for prunes is about two-thirds that at or below 40 per cent relative humidity.

Static Air Pressure. Static pressure may be considered as the pressure necessary to overcome the frictional resistance offered to the flow of air. It is measured by means of a Pitot tube and is expressed in inches of water pressure.

Velocity Pressure. Velocity pressure is that pressure required to create the velocity of air flow. Total pressure, or dynamic, or impact, pressure, is that pressure required to overcome frictional resistance and to create the velocity of flow, and it is the sum of the static and velocity pressures.

Pitot Tube. This instrument consists essentially of two parts: (1) a tube pointing upstream against the flow of air, converting the sum of the static pressure and velocity pressure into a head that may be measured; and (2) a means of determining static pressure alone. For the latter measurement

the Pitot tube is fitted with two openings 0.02 in. in diameter. These openings connect with a tube, which in turn is attached to an inclined manometer filled with a light liquid such as gasoline, which gives a sharp meniscus. The total-pressure orifice is also connected to a similar inclined manometer by flexible rubber tubing.

The pressures are reported in inches of water, due allowance being made for the specific gravity of the liquid used in the manometer and for the inclination of the manometer. Perry et al. (1946) point out that since a Pitot tube shows only $\frac{1}{10}$ to $\frac{1}{16}$ in. differential at a velocity of 1,000 ft. per min., it is not as well adapted as an anemometer for measuring air velocity in dehydraters.

Calculation of Air Velocity. The difference between the total and static pressures is the velocity pressure, from which the air velocity can be calculated by the following formula:

$$V = 4{,}101 \sqrt{p}$$

where p = velocity pressure in inches water gauge determined by actual test, and V = velocity in feet per minute (calculated from p).

Effect of Revolutions per Minute of Fan. The volume of air discharged by a fan varies within limits directly as the number of revolutions, and the pressures produced vary as the square of the revolutions. The power required to operate the fan varies as the cube of the revolutions. These facts explain the startling increase in horsepower required for the operation of fans when the revolutions per minute and volume of air delivered are increased by moderate amounts.

Effect of Static Pressure. Static pressure is increased by decreasing the size of air ducts, by increasing their length, or by inserting sharp bends. Static pressure also increases with the square of the air velocity, and therefore in comparing the static pressures of any two dehydraters, the relative air velocities must be taken into account. The volume of air delivered by the fan decreases as static pressure increases. Thus, a fan that delivers 23,600 cu. ft. of air at 350 r.p.m. and 1 in. static pressure will deliver only 14,700 cu. ft. at 2 in. static pressure.

Air ducts should be large so that static pressure is not excessive, and for the same reason the distance between trays should be great enough to permit relatively unimpeded air flow. The velocity of air in return flues or passageways between the fan and the drying compartment should not exceed 1,000 ft. per min., so that static pressure will not be excessive.

The static pressure in several typical air-blast dehydraters in California was found to range from 0.52 to 2.63 in.

It is difficult to set a standard for maximum static pressure for dehydraters, but for a horizontal air-blast tunnel dehydrater 50 ft. in length and approximately 50 sq. ft. in cross section, the static pressure should not

exceed 2 in. at an air velocity of 500 ft. per min. when the tunnel is filled with cars and trays of fruit.

Recirculation of the Air. If the air used in drying fruit or vegetables is allowed to escape into the outside atmosphere after its passage through the dehydrater, a great deal of heat is lost. For example, if 10,000 cu. ft. of air per minute is used, heated from 60 to 160°F., and in going through the dehydrater drops to 120°F., it will still be at a temperature 60°F. above that of the outside air. If the air is returned to the heating chamber and is used

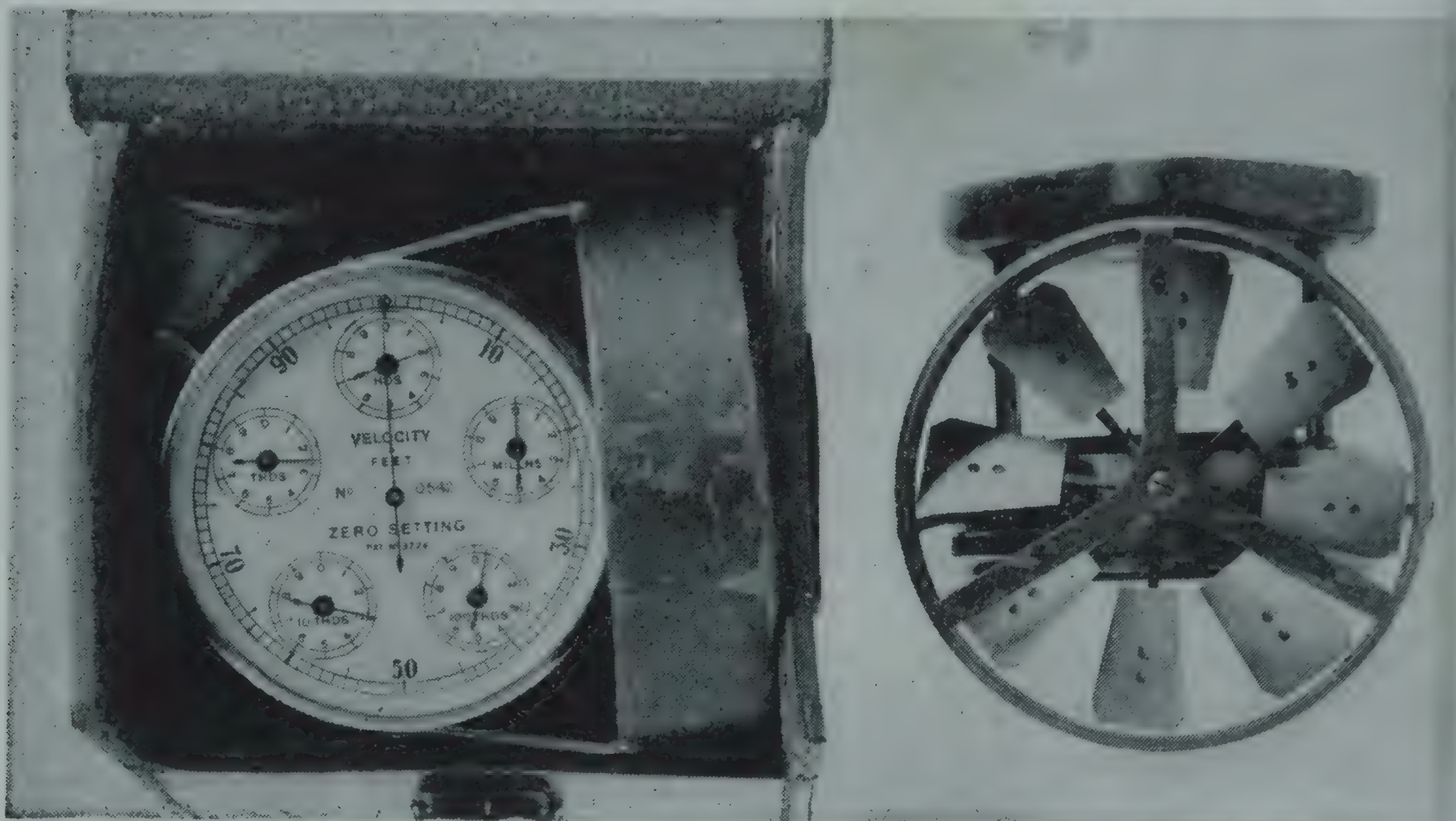


FIG. 89. Anemometer for measurement of air flow in dehydraters.

again, this heat will be conserved; or conversely, if fresh air is drawn into the dehydrater to replace that discharged from it, approximately twice as much heat is required to heat the fresh air as is required to heat the spent air.

Certain fruits caseharden, i.e., become overdried on the surface, and drying thereby is retarded. This condition is avoided to a large extent if the relative humidity of the air is increased sufficiently, which can be done to a large degree by return of some of the spent air. Because of these facts, it is customary in modern dehydraters to provide for recirculation of a portion of the air used in drying.

In the dehydraters ordinarily used in California, it is found desirable to close the air-escape damper partially and to operate the dehydraters with recirculation of most of the air in the drying of prunes, apricots, peaches, and pears, and with recirculation of none or only a small per cent of the air in the dehydration of apples, sliced vegetables, and other rapidly drying materials. In the drying of walnuts most of the air is discharged without recirculation.

In an experiment made by the author at the University of California, it was found that recirculation of most of the air during the drying of prunes resulted in a saving in fuel of approximately 50 per cent.

Air Distribution. Not only must the dehydrater be furnished with a sufficient volume of air, but the air so furnished must also be applied to the product to be dried in an evenly distributed manner.

Frequently the space above the topmost tray on a dehydrater car is too great, and an excessively large proportion of the air flows through this space; or it may flow beneath the cars or beside them instead of between the trays.

By the placing of baffles on the walls of the dehydrater or on the cars, it is usually possible to force the air into the desired channels. Table 38 gives the results of air-flow measurements in a dehydrater before and after installation of air baffles.

TABLE 38. EFFECT ON AIR DISTRIBUTION OF PROPER PLACING OF BAFFLES

Location of test	Velocity before installing baffles, ft. per min.	Velocity after installing baffles, ft. per min.
Velocity of air between trays near top of car	320	600
Velocity of air between trays near bottom of car	400	420
Velocity of air below cars	1,500	500
Velocity of air above top tray	2,800	500

SOURCE: After Cruess and Christie.

Methods of Obtaining Air Flow. Two means of obtaining air flow in dehydraters are in commercial use. These are by natural draft and by forced draft. In the former method the tendency for hot air to rise is used; in the second method some form of fan is employed to force the air through the dryer. Natural-draft and forced-draft dehydraters will be discussed in greater detail later in this chapter.

Parallel- and Countercurrent Systems of Drying. In most tunnel dehydraters the fresh fruit enters at the air-exhaust end and the dried fruit leaves at the air-intake end of the drying compartment. During drying, the fruit is moved from air of moderate temperature (100 to 120°F.) at the start of drying to temperatures of 150 to 170°F. near the end of the drying period. This is termed the "countercurrent system." During the first stages very little drying occurs because of the moist condition and relatively low temperature of the air. The drying process is completed in air of high temperature and low relative humidity.

In the so-called "parallel-current system," the fruit enters at the air-intake end of the drying compartment and is taken from the dehydrater at

the air-exhaust end; the drying process is started in hot, dry air and is completed in warm, moist air. For some fruits this system possesses the following advantages:

1. Evaporation of the surplus moisture is very rapid during the initial stages of the drying period when the fruit is moist and in the best condition to give up its water.

2. The wet fruit is more nearly at the temperature of the wet-bulb thermometer because the fruit contains sufficient moisture to maintain a rapid rate of evaporation that reduces its temperature proportionately, permitting higher drying temperatures than are now used and thus still further increasing the rate of drying. In the countercurrent system the fruit near the end of the drying process, because of its low moisture content and slow rate of drying, is very apt to approach the temperature of the hot, dry air and becomes scorched and caramelized. The parallel-current system takes fuller advantage of the drying power of air but may increase the loss of juice in the early stages of drying.

3. The fruit gradually progresses during drying toward a region of lower temperature and higher humidity, so that scorching and overdrying are minimized.

4. The fruit emerges after drying at a relatively low temperature, so that much less heat is carried to the outside atmosphere by heated cars, trays, and fruit than is the case with the countercurrent system. The principal objection to the parallel system is the extremely slow rate of drying near the end of the tunnel.

The countercurrent has proved more satisfactory than the parallel-current system for the dehydration of prunes.

Two-stage Dehydration. As it is extremely difficult to get the fruit sufficiently dry in a parallel-current dehydrater, this is generally used only as the first stage in the so-called "two-stage system" of drying. The fruit is partially dried by parallel current and is then finished in a countercurrent tunnel. This system is in use in Canada for drying apples. It is sometimes known as the Eidt system, for C. C. Eidt of Canada. See also Chapter 19, Dehydration of Vegetables.

Methods of Heating Air. The air used in dehydration in commercial plants is in some cases heated by contact with steam pipes or with large flues heated by the products of combustion of natural gas, crude oil, wood, coal, or other fuel. It may also be heated by means of electrically heated wires or grids, or by mixing with the products of combustion of a clean-burning fuel, such as stove distillate, kerosene, or gas. All these methods are used commercially.

The method in which the products of combustion are mixed with the air used in drying is the most efficient because radiation and stack losses are

reduced to a minimum. It is now the usual method in California, with natural gas as the preferred fuel.

Area of Heating Surface. Formulas exist for the calculation of the area of the heating surface required for the heating of a given volume of air. Expressed in the metric system, one formula is as follows (after Hausbrandt):

$$H = \frac{Cg}{tm(2 + \sqrt{c})}$$

where H = area of the heating surface in square meters, tm = mean difference in temperature between heating surface and air, c = velocity in meters per second, Cg = calories per hour.

The coefficient of heat transmission k varies with the square root of air velocity in accordance with the following formula:

$$k = 2 + 10\sqrt{c}$$

where c = velocity of the air in meters per second.

From the first formula given above, it is also evident that heat transfer varies directly with the difference in temperature of the heating surface and the air undergoing heating.

From these considerations it would appear advisable to maintain the heating surface at a relatively high temperature and to carry the air through the heating chamber with fairly high velocity. If the air is conducted from the cooler to the warmer portions of the heating system, a larger proportion of the heat will be absorbed by the air than if it is conducted in the opposite direction.

Fuel Efficiency. We may define fuel efficiency as that proportion of the total heating value of the fuel actually utilized in evaporating moisture from the fruit. For example, if an amount of fuel is burned sufficient to evaporate 1,000 lb. of water and if only 500 lb. of water is evaporated, the fuel efficiency is 500/1,000, or 50 per cent.

Since approximately 1000 B.t.u. of heat is required to evaporate 1 lb. of water and since 1 gal. of fuel oil will furnish approximately 142,000 B.t.u., a simple formula for calculating the efficiency of a given dehydrater is the following:

$$\frac{\text{Pounds fresh fruit} - \text{pounds dry fruit}}{\text{Gallons of oil consumed} \times 142} = \text{fuel efficiency}$$

Data were collected upon a number of dehydraters in California, and their efficiencies were calculated by means of the above formula, with the results shown in Table 39.

TABLE 39. COMPARATIVE FUEL EFFICIENCIES OF SEVERAL TYPES OF DEHYDRATERS

Plant no.	Type of dehydrater	Fruit dried	Fuel efficiency, %
E	Air-blast tunnel, indirect heat	Apricots	58
N	Ceramic oven	Apples	50
F	Air-blast tunnel, direct heat	Grapes	48
N	Ceramic oven	Grapes	44
E	Air-blast tunnel, indirect heat	Peaches	43
E	Air-blast tunnel, indirect heat	Pears	43
B	Air-blast tunnel, indirect heat	Prunes	42
J	Air-blast tunnel	Prunes	39
J	Air-blast tunnel (same design as preceding but in another location)	Prunes	38
E	Air-blast tunnel, indirect heat	Grapes	38
H	Air-blast cabinet	Prunes	30
M	Stack-type gravity air flow	Prunes	24
M	Small stack-type gravity air flow	Apricots	14

SOURCE: After Cruess and Christie, *Univ. Calif. Agr. Expt. Sta. Bull.* 337.

A well-designed dehydrater should have a fuel efficiency, calculated by the above formula, of at least 40 per cent in drying prunes or grapes. An efficiency above 50 per cent is very difficult to attain under usual conditions.

The per cent of the total heat units of a fuel actually utilized in heating the air may be considered the heating efficiency of the furnace and fuel and is much higher than the heat units used in evaporation of H_2O from the fruit.

Effect of Temperature of Air on Drying Rate and Efficiency. The capacity of air to take up moisture rapidly increases with rise of temperature, and the amount of heat necessary to evaporate a given weight of water decreases with rise in temperature (see Table 30).

Critical Temperature. The temperature of the air used in dehydration greatly affects not only the time required for drying, but also the quality of the finished product. In order to secure large capacity and minimum operating costs, it is necessary to use the highest temperature that will not materially injure the product. Most dehydraters that involve a progressive movement of the fruit through the drying chamber have used the countercurrent system. The "critical temperature" for any fruit is the temperature at which, when the fruit is almost dry, it may undergo undesirable changes in color or flavor. In the countercurrent system this temperature is the maximum that can be used, while in the parallel-current system this temperature must not be exceeded in the final stages of drying, although much higher temperatures can be used while the fruit still contains an excess of moisture.

Experiments by Gadgil, Winkler, and Bjarnason, at the University of California, indicated rapid loss of sugar when raisins were heated to 185°F. after becoming nearly dry. At lower temperatures the effects were negligible unless the raisins were allowed to become very much overdried, a condition that should never occur in a commercial plant.

Relative Humidity. Relative humidity of air may be defined as its percentage of saturation with moisture vapor. Air completely saturated with water vapor at a given temperature is at 100 per cent relative humidity; air at the same temperature containing one-half the amount of water vapor that it is capable of absorbing is at 50 per cent relative humidity. The absolute amount of water vapor that air can absorb (within certain temperature limits) approximately doubles with each 27°F. rise in temperature.

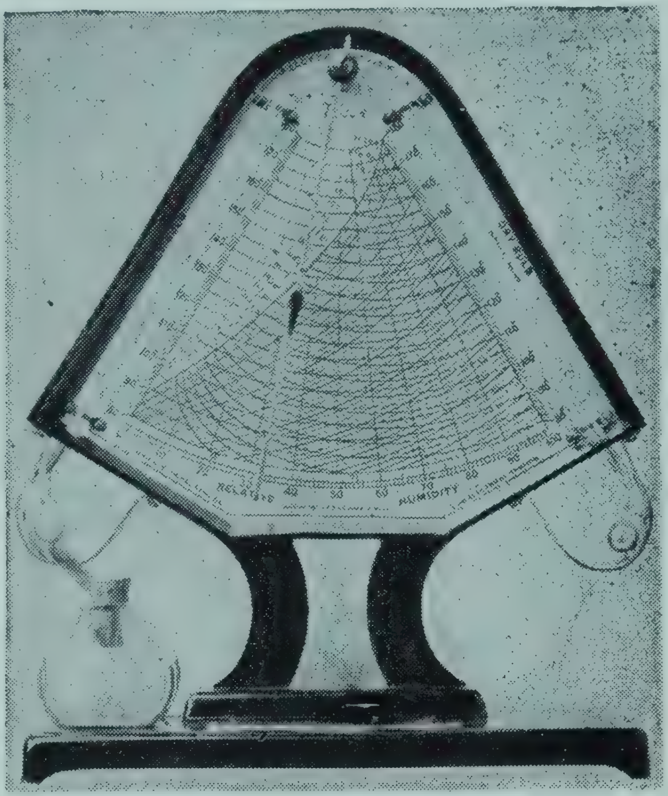


FIG. 90. Wet- and dry-bulb thermometers of types commonly used for measuring relative humidity in dehydraters.

Casehardening. Large pieces of fruit, such as halved pears, peaches, or whole Imperial prunes, caseharden if the relative humidity is so low and the temperature so high that the moisture is removed more rapidly from the surface than it diffuses from the interior of the fruit. Casehardening (searing over of the surface) retards the rate of evaporation because it impedes the diffusion of water to the surface of the fruit.

In drying pears and peaches it has been found that casehardening was materially reduced by increasing the relative humidity of the air at 150°F. to 30 to 35 per cent.

Thinly sliced fruits (e.g., pears, apricots, and peaches), dipped grapes, small- to medium-sizes prunes, and dipped cherries do not caseharden seriously.

Dew Point. Relative humidity may also be defined as the ratio of the vapor pressure of the water vapor present in a given space to the vapor pressure of water vapor in that same space saturated with water vapor. The saturation point is ordinarily known as the dew point (i.e., 100 per cent relative humidity).

Determination of Relative Humidity. Relative humidity is determined by comparison of the temperature of wet- and dry-bulb thermometers. Evaporation of moisture from the wet-bulb thermometer causes a drop in temperature in proportion to the rate of evaporation, which is dependent

upon the relative humidity of the air. Table 40, published by the Foxboro Instrument Company, gives the relation between wet bulb, dry bulb, and relative humidity for temperatures commonly met with in the dehydration of fruits.

In using the table, in the topmost horizontal row find the difference in temperature nearest that of the observed *difference* in temperature between the wet- and dry-bulb thermometers. Follow down the vertical column directly beneath this difference in temperature until this vertical column cuts the horizontal row opposite the dry-bulb thermometer temperature. The figure at the point of intersection is the relative humidity. An example will make this explanation clearer:

Dry-bulb reading, 130°F.; wet-bulb reading, 103°F.; difference, 27°F. In Table 40, 28° is the nearest temperature given. Follow down 28°F. column until the horizontal row opposite 130°F. is met. At this point of intersection

TABLE 40. RELATION OF HUMIDITY TO DIFFERENCE IN TEMPERATURE OF WET- AND DRY-BULB THERMOMETERS

Dry bulb, °F.	Difference between readings of wet and dry bulbs, °F.																																				Dry bulb, °F.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60	65	70	
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	12	6	0	0	..	..	..	..	..	..	..	..	..	..	..	..	70
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	18	12	7	1	0	..	..	..	..	..	..	..	..	..	..	..	75
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	23	18	12	7	3	0	..	..	..	..	..	..	..	..	..	..	80
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38	35	32	27	22	17	13	8	4	0	0	..	..	..	..	..	..	..	..	85
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	31	26	22	17	13	9	5	1	0	..	..	..	..	..	..	..	90
95	96	93	89	85	82	79	75	72	69	66	63	60	57	54	52	49	46	43	42	38	34	30	25	21	17	13	9	6	2	0	..	..	..	..	..	..	95
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	37	33	28	24	21	17	13	10	7	4	0	..	..	..	..	..	100
105	97	93	90	87	83	80	77	74	72	69	66	63	60	58	55	53	50	48	46	44	40	36	32	28	23	20	16	13	11	8	0	..	..	..	..	..	105
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	42	38	34	30	26	23	20	17	14	11	4	0	..	..	..	..	110
115	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	57	54	52	50	48	43	40	36	32	28	26	22	20	16	14	7	2	0	..	..	..	115
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	45	41	38	34	31	28	25	22	19	17	10	5	0	..	..	..	120
125	97	94	91	88	85	83	80	78	75	73	70	68	66	63	61	59	57	54	52	50	47	43	40	36	33	30	27	24	22	19	13	7	2	0	..	..	125
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	48	45	41	38	35	32	29	26	24	21	15	10	6	1	0	..	130
135	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	50	46	43	40	36	34	30	28	26	23	18	12	8	3	0	..	135
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60	58	56	54	51	47	44	41	38	35	32	30	27	25	19	14	10	5	2	..	140
145	98	95	93	90	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	52	48	45	42	39	36	34	31	29	27	21	16	12	7	4	0	145
150	98	95	93	90	87	85	82	80	78	76	73	71	70	68	65	64	62	60	58	56	53	49	46	43	41	38	35	33	30	28	23	18	13	9	5	2	150
155	98	95	93	90	87	85	83	81	79	76	74	72	70	68	66	64	63	61	59	57	54	50	47	44	42	39	37	34	32	30	24	19	15	11	7	4	155
160	98	95	93	90	88	85	83	81	79	77	75	73	71	69	67	65	63	62	60	58	55	51	48	46	43	40	38	35	33	31	25	21	16	12	9	6	160
165	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	56	52	49	47	44	41	39	37	34	32	27	22	18	14	10	7	165
170	98	96	94	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	57	53	50	48	45	42	40	38	35	33	28	23	19	15	12	9	170
175	98	96	94	91	89	86	84	82	81	79	76	74	73	71	69	67	66	64	62	61	58	54	51	49	46	43	41	39	36	34	29	25	20	17	13	10	175
180	98	96	94	92	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	58	55	52	50	47	44	42	40	37	35	30	26	21	18	14	12	180
185	98	96	94	92	89	87	85	83	81	80	77	76	74	72	70	69	67	65	64	62	59	56	53	50	48	45	43	41	38	36	31	27	22	19	16	13	185
190	98	96	94	92	90	87	85	83	82	80	78	76	74	73	71	69	68	66	64	63	60	57	54	51	49	46	44	42	39	37	32	28	24	20	17	14	190

SOURCE: After The Foxboro Company, Inc., Foxboro, Mass., Catalogue 101-1, p. 9.

will be found 38, the approximate per cent relative humidity. More accurate results are obtainable by interpolation or by use of a relative-humidity chart.

Vapor Pressure. The pressure causing water to evaporate is vapor pressure. The vapor pressure of partially saturated air may be calculated by various formulas from wet- and dry-bulb readings (Carrier).

Temperature of Products. It is reasonable to suppose that as long as the evaporation is not forced beyond the ability of the material undergoing drying to part with its free water, its temperature will be essentially that of the wet-bulb thermometer and its vapor pressure will be that of the saturated vapor at that temperature. When the attempted rate of evaporation is greater than that at which the material can give up its moisture, the temperature of the material will rise above that of the wet-bulb thermometer, and the condition will be like that of an autoclave from which the rate of flow is controlled by a cock.

Heat Losses. The greatest heat loss in dehydration is that in the exhaust air. Under some conditions this may amount to 50 per cent of the total heat generated in the furnace and is frequently more than 25 per cent of this total. By recirculation of some of the air this loss can be greatly reduced but not entirely eliminated under practical working conditions.

Leakage of air through cracks or around doorsills, etc., and radiation of heat from the walls may also become serious causes of heat losses.

Considerable heat is lost in the gases from the stack of the furnace or boiler in plants in which the air is heated by indirect heat. With a properly designed and operated furnace and radiating-pipe type of heating apparatus, the temperature of the flue gases at the outlet of the stack should not be above 200°F. In plants in which the products of combustion heat the air directly, there is no stack loss.

TYPES OF DEHYDRATERS

Many forms of dehydraters are in commercial use, and many others have been patented but not used commercially. It many cases dehydraters have been designed and built but have failed to perform satisfactorily because the fundamental principles of dehydration were not understood or considered.

A satisfactory dehydrater should permit close control of temperature, air velocity, and relative humidity.

Because of space limitation it is impossible to give in this book complete plans and specifications for even the more important types of driers. A brief description only of the more important features of dehydrater types in commercial use will be given. A list of bulletins of state experiment stations and of the U.S.D.A. and other publications, some of which give

working specifications for various evaporators and dehydraters, will be found at the end of this chapter.

In general, we may place driers in three classes, viz. (1) natural-draft driers, (2) forced-draft driers, and (3) distillation driers, including those operating under vacuum.

Natural-draft Driers. Most of the driers used in New York State and California for the drying of apples and hops and in Oregon and Washington for the drying of apples are of the natural-draft type, which requires no fan. However, many of these, particularly kilns, are equipped with fans. They possess the advantages of simplicity of construction and operation. Although inefficient in their use of fuel, they are relatively inexpensive to build.

Natural-draft driers, in general, consist of a furnace room or steam pipes surmounted by a drying chamber. Cold air enters the furnace room near the ground level and is heated by contact with the furnace radiating pipes or steam coils and rises through the drying compartment, where it comes in contact with the fruit or other product undergoing drying.

Kiln Drier. The kiln drier, one of the oldest types still in commercial use for the drying of apples and hops, is constructed in two stories. The upper story houses the drying floor, which is usually about 20 ft. square and made up of strips of hardwood ¼ in. apart. Over the floor is a steep four-sided roof, equipped at the apex with a large ventilator for the escape of spent air. The prepared fruit or other product is placed directly on the floor in a layer 3 to 12 in. or more in depth and is stirred with a fork or scoop shovel during drying.

The furnace room houses a large natural-gas, wood-, coal-, or oil-burning furnace connected to a series of large sheet-metal pipes that are led around the furnace room several times before joining the stack. In some installations the furnace and radiating pipes are replaced with a steam boiler and steam pipes, the latter being placed immediately beneath the drying floor. While more expensive to install, the steam-heated kiln permits of more careful regulation of the temperature and makes possible the use of higher temperatures than is feasible with the usual tower drier and former type of kiln. The drying rate can be increased by installing a fan in the ventilating duct. Most kilns are now so equipped.

The kiln drier is satisfactory for hops and gives fairly satisfactory results in the drying of apples but is unsuited to the drying of soft fruits, such as prunes, grapes, peaches, etc., because of bruising (for details of construction see Caldwell).

Tower Drier. The "tower," or "stack," drier consists of a furnace room about 10 ft. in height, in which are located a furnace and heating pipes of the same general design as the heating system used for the Oregon tunnel drier, and of cabinets in which trays of fruit are dried. Each stack, or

cabinet, holds about 12 trays, usually 3 ft. square in size, and each furnace room usually accommodates six stacks of trays. The heated air from the furnace rises through the trays.

In operating this drier the cabinets are filled with trays of the fresh fruit, and as the trays at the bottoms of the stacks become dry, they are removed and are replaced with freshly loaded trays, which are entered on the topmost tray runways. Each time a fresh tray enters the stack the whole set of trays is shifted downward one tray.

Cabinet Drier. This drier may be similar in design and in operation to the

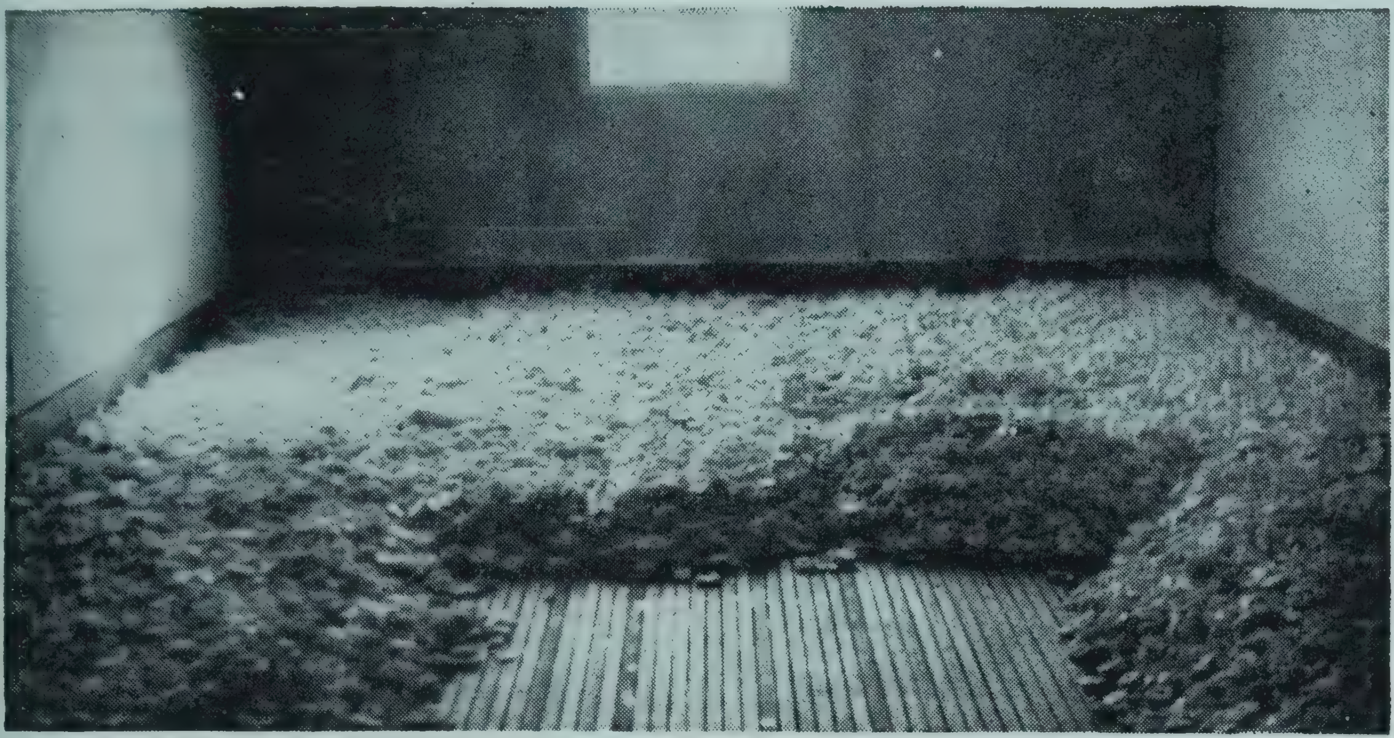


FIG. 91. Apple kiln, partially loaded, showing slatted floor.

stack drier, but heat for drying is furnished by steam coils placed between the trays. Drying is rapid, and the temperature can be very conveniently and exactly regulated. It is a very great improvement over the old stack drier (for details of construction see Beattie). The name "cabinet drier" is also applied to a compartment holding trays across or through which heated air is blown.

Oregon Tunnel Drier. This was the most common drier formerly in use in the Pacific Northwest. It was invented by Allen and is often known by his name.

In a general way, it may be described as a series of parallel, sloping narrow chambers above a furnace room. The trays of fruit enter the drier at the upper or cooler end on runways and progress toward the lower or warmer end. The dry fruit is removed from the lower end of each tunnel. The furnace room is similar in design to that used for the kiln drier, and the drying tunnels rest on a floor about 12 to 16 ft. above the floor of the furnace room, which serves two to four tunnels. Each tunnel is about 20 ft. long by about 5 ft. in height by about 3 ft. in width and slopes approxi-

mately 2 in. per ft. At one time tunnels were much longer than 20 ft., but more rapid and uniform drying is obtained by the shorter tunnels. Hot air enters the lower end of each tunnel through an opening, or "throat," approximately 3 ft. wide, which is fitted with a sliding door by means of which the amount of air passing through the drier can be regulated.

In recent years many owners of tunnel driers have installed fans by means of which most of the air is recirculated and the efficiency of the tunnels greatly increased.

There is a considerable difference in the temperature of air at the upper and lower ends of the tunnel, a fact that renders the tunnel drier more efficient in its use of fuel and heat than tower or kiln driers, but nevertheless the Oregon tunnel is less efficient than air-blast driers. The temperature at the upper end of the tunnel is usually 30 to 50°F. lower than at the furnace end, and on this account the tunnel drier is especially well adapted to the drying of prunes.

Ceramic Oven. Driers built on a design similar to that of a bake oven have been built in California. The walls are of heavy masonry and firebrick, and heat is radiated from the walls, ceiling, and floor to the fruit, which is held on trays on trucks. Owing to uneven and slow drying of the fruit occasioned by inadequate air flow, this drier was later equipped with forced draft and a recirculation system, which together notably improved the rate of drying. It is, however, no longer being built in California.

Drying by Infrared Heat. Heat from infrared lamps has been used for the dehydration of macaroni cut in short lengths, according to a report by the staff of *Food Engineering* (1955). Probably this source of heat could be utilized for the drying of fruits and vegetables. The principal obstacle would probably be the relatively high cost of the electric energy needed.

Distillation Type at Atmospheric Pressure. In this type of drier the moisture is driven from the product by heat, and the water vapor so evolved is condensed by water-cooled coils or by sprays of cold water. This principle has not been applied commercially to the drying of fruits, although it is used in lumber kilns.

Vacuum Dehydraters. Vacuum dehydraters are in use for the drying of some chemicals and other manufactured products that are easily injured by high temperatures and oxidation. Drying *in vacuo* permits the use of low temperatures of drying and minimizes oxidation, but the equipment needed is rather complicated and expensive and for these reasons has not found general application in the drying of fruits and vegetables.

In its commercial form, the vacuum dehydrater consists of a heavy-walled sheet-metal or cast-iron chamber fitted with steam-heated or electrically heated shelves or coils on which rest trays of the material to be dried. Circulating heated water is also used for heating the hollow shelves used in shelf-type vacuum driers. The chamber is connected with a vacuum

pump and spray or coil condenser for maintaining a high vacuum and for condensing moisture liberated in the drying compartment.

Dehydration in a vacuum requires less heat than in a drier operating with heated air, because most of the heat supplied to the vacuum drier is used in the evaporation of moisture.

Since it reduces the tendency for fruits to darken, possibly the vacuum method of dehydration may be employed as a means of reducing the length of sulfuring of fruit before dehydration, or in some cases of completely eliminating sulfuring. It is used by one Californian producer, the Vacu Dry Corp. of Oakland, California, for drying previously dried fruits to a bone-dry condition in order that they may be ground to a powder. However, a more common procedure in this plant consists in first cutting the dried fruit by machine into small pieces. These are then dried *in vacuo* to less than 2 per cent moisture content and packed in hermetically sealed or friction-top cans that will exclude moisture. This product is known in the trade as "fruit nuggets." The stainless-steel shelves on which the fruit is dried are heated by electricity under very close control. Toward the end of the drying cycle the temperature is raised sufficiently for a short time to cause "puffing" of the nuggets. Because of this condition the nuggets absorb water very quickly in cooking or if merely placed in cold water.

Forced-draft Tunnel Dehydrater. The forced-draft tunnel dehydrater has proved to be the most efficient type of drier in commercial use in California for the drying of fruits. It also permits of most rapid drying without injury, is the least costly dehydrater to build and to operate, and permits of more uniform drying. It normally consists of a chamber longer than wide, through which the product to be dried moves progressively on trays. The drying chamber, or tunnel, is supplied with a current of heated air that is introduced at one end and removed from the opposite end.

In the Progressive dehydrater the cars of loaded trays are located in a tunnel on each side of which is a secondary tunnel. Auxiliary fans blow the heated air across the cars in the central tunnel. The direction of air flow is reversed periodically.

Methods of Heating the Air. The air used in forced-draft driers is heated in one of four ways: by steam coils, by electrically heated grids, by hot-air furnaces, or by mixing with the products of combustion from the furnace. Electric heating is the most expensive method to install and operate but allows exact regulation.

Hot-air furnaces and heating systems have been described for the kiln drier. Similar systems are in use for heating air in forced-draft driers of all types. In using electricity for heating, the air is passed over grids of resistance wire heated by passage of electric current. It is used only for high-priced products such as candied fruits and some walnuts.

Direct heating of the air by mixing it with the products of combustio has been used successfully in dehydraters and now is the usual systen employed in California plants. Fuel is burned in a furnace in which i built a checkerwork of firebrick, which breaks up the flame and favor complete combustion. The products of combustion are mixed with col outside air or that returned from the drying chamber, and the mixe gases are drawn through the fan and forced into the tunnel. The therma efficiency of this system is greater than either the steam-heating or hot-ai furnace systems. Figure 88 illustrates the direct air-heating system.

Direct heating requires a special grade of fuel, viz., gas, stove distillat engine distillate, or kerosene. In the drying of white fruits there is som danger of blackening the fruit from the formation of soot in the furnac through incomplete combustion caused by clogging of the burners o temporary stopping of the motor operating the air line for the burner

Perry et al. (1946) emphasize that the furnace shell must be large enoug to permit complete combsution when oil or distillate is used. A rough guid given by them is that 1/5 to 2/5 gal. of oil can be burned per hour per cubi foot of furnace volume; or 20 gal. per hr. can be burned in a shell of 3 in. diameter and of customary length. The length of the furnace to th first baffle should be that specified by the manufacturer of the burner. Th baffles are of firebrick arranged in checkerboard fashion with air intakes o generous size between the bricks. The first baffle ensures a hot firebox wit a low flame, and the second baffle provides for complete combustion of th fuel with a high flame.

The air supply must be adequate to maintain a good flame but also o sufficient volume to keep the temperature in the furnace below 2700°F. the softening point of the brick and refractory lining. According to Perr et al., this requires about 2,700 cu. ft. of air per gallon of oil burned pe hour. The air-intake openings in the furnace front must be large enoug to allow the furnace to operate at low draft.

Most of the air used in drying does not pass through the furnace bu is mixed with the products of combustion by a fan situated between th furnace and the drying tunnel (Figure 88).

Fans. The heated air is either forced through the tunnel under positiv pressure by means of a blower fan or is drawn through the tunnel by mean of a suction fan. Both are satisfactory. Where a suction fan is used, th tunnel should be equipped with air locks at each end so that the cars o trays may enter and be removed from the tunnel without excessive re- duction in temperature.

Fans are of several types: disk, multivane, airplane propeller, axial-flow paddle wheel, and others. Under most conditions the multivane type o fan is to be preferred to the disk fan. The disk fan, which resembles a windmill in appearance, is low-priced but will not deliver air agains

appreciable static pressure. The paddle-wheel fan is similar in principle to the multivane but has fewer vanes. It is thoroughly satisfactory. The airplane-propeller type fan is also quite satisfactory. The axial-flow fan is used very successfully in dehydraters. Perry et al. (1946) give the general features, horsepower requirements, and other engineering characteristics of centrifugal and axial-flow fans used in dehydraters (Figure 92).

Relative Position of Furnace and Tunnel. The furnace room may be

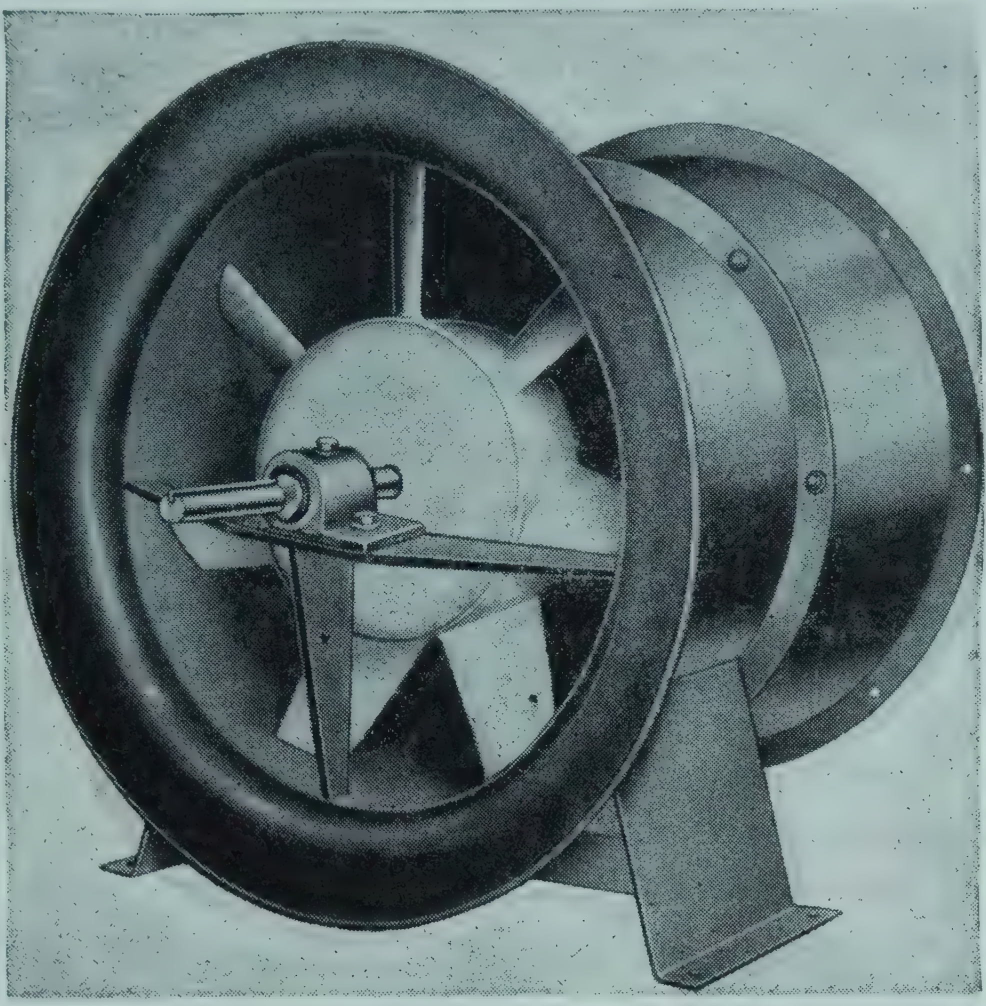


Fig. 92. Sturtevant Axiflow fan. Used frequently in prune dehydraters. (*Sturtevant Division of Westinghouse Electric Corp., Boston.*)

located at one end of the tunnel, at the side, or above or below the tunnel. It is advisable that it be so placed that the cars or trays may enter one end of the tunnel and be removed from the opposite end without the necessity of transferring to separate cars. A very convenient arrangement is that in which the furnace and heating systems are located in a tunnel beside the drying tunnel, with the fan located in the furnace room. Air is delivered to the drying tunnel by a duct beneath the floor or in the wall of the drying tunnel. No air locks or transfer systems are required under these conditions (Figure 88).

Cars. The material to be dried is usually spread on trays, which are carried through the tunnel either on cars or on runways, as in the Oregon tunnel drier. The car system is the one more generally used. The cars operate on tracks in most cases, but they may be equipped with caster wheels to permit moving to any part of a concrete floor in the preparation room or drier, or they may be carried by an overhead conveyer.

In small tunnels the cars are moved by hand; in large plants they are drawn by a winch or by other power.

Recirculation. It is desirable that the forced-draft tunnel dehydrater be so constructed that any proportion of the air may be recirculated. The return-air duct must be large enough to permit unimpeded flow of the air, in order that static pressure shall not be excessive. The position of the return flue is optional, as it may be above, below, or at one side of the tunnel. The furnace room may be so placed that it serves as a return flue, as in Figure 88.

Other Types of Forced-draft Dehydraters. The stack drier and Oregon tunnel driers have, in some instances, been equipped with a fan to improve air circulation. Most kiln driers are now equipped with fans. The results obtained have more than compensated for the cost of such installations.

Continuous draper or belt tunnel driers are in use for the drying of vegetables, starch, soap chips, etc. The drier consists of a tunnel with several woven metal-cloth endless conveyers placed one above the other. Air heated by steam coils is in one type blown lengthwise of the tunnel by a single large fan and in another type is blown across the trays, at right angles to the greater diameter of the tunnel, by several fans placed at the side of drying compartment. One serious objection to the draper drier is that the drying area is much less than in a dehydrater of equal volume using trays. See the section on onion dehydration in Chapter 19 for additional discussion of continuous dehydraters.

In one type of air-blast cabinet drier the trays are placed on runways in cabinets. Air is delivered between each pair of trays by a small duct, or "tuyere," and the direction of flow is reversed frequently to ensure uniform drying at all points on the trays. This drier is unnecessarily complicated.

In other cases the air is forced upward through the trays, but resistance to air flow is so great that drying is slow and uneven.

Trays. Dehydrater trays vary greatly in size, design, and materials of construction.

Screen Trays. The most common tray used in the tower and Oregon tunnel driers is made of a wooden frame and galvanized-iron wire screen. The size of the trays is usually 3 by 3 ft. or 3 by 4 ft. These trays are satisfactory for unsulfured fruits, but the zinc coating rapidly corrodes in sulfur fumes, and the fruit absorbs zinc salts and acquires a metallic taste. With continued use, the zinc is completely removed and the iron is exposed. This dissolves in fruit juices and reacts with the tannin of fruits to give iron tannate, causing the fruit to blacken where it comes in contact with the screen. No satisfactory coating has been found for such trays.

Slat Trays. The most satisfactory tray for general use is the slat-bottom

tray, about 6 by 3 ft. or 3 by 3 ft. in size. The 6 by 3 size is the more common in California. It may consist of narrow wooden strips attached to a wooden frame with sides of 1½- by 3-in. material and ends of 1- by 2-in. pieces, when used on trucks in forced-draft dehydraters. The height of the sides may be greater or less than that given above, and the size of the trays larger or smaller, as desired.

Solid wooden-bottomed sun-drying trays are sometimes used in driers, particularly following early fall rains, in salvaging rain-damaged fruit. When such trays are used, wooden strips must be placed between the ends to provide space for passage of the air. Drying is slower than on screen trays.

Trays 6 by 3 or 8 by 3 ft. in size are not satisfactory where the air flows across the greater length of the tray, because the fruit on the end of the tray nearest the source of heat dries more rapidly than fruit at the opposite end; or if the direction of air flow is reversed frequently, the fruit near the middle of the tray dries more slowly than at the two ends. The trays are placed crosswise of the tunnel; hence the air travels across the short diameter only.

Tray Capacity. At the University of California dehydrater at Davis, trays held 2 lb. of medium-size halved apricots per square foot, 3 lb. of medium-size halved Muir peaches, 3 lb. of halved pears, 2½ to 3½ lb. of prunes one layer deep, and 3 to 4 lb. of grapes. Sliced or cubed apples and cubed vegetables are loaded on trays at the rate of about 1 to 2 lb. per sq. ft.

Plant Investment. For the average fruit grower the plant investment should be as low as is compatible with reasonable efficiency, because the duration of the fruit season is so short that it causes the overhead cost of plant investment to be excessive unless the construction cost is low.

Cost per Ton Capacity. A survey of dehydraters in California showed that it was possible to erect an efficient and satisfactory dehydrater for approximately $1,000 per ton of green fruit dried per 24 hr. The cost of buildings and accessory equipment is additional.

Comparative Costs of Operation. The cost of drying prunes and grapes in several types of dehydraters is shown in Table 41. Present costs are considerably higher, but the data are useful for comparative purposes.

Natural-draft driers showed a higher operating cost than forced-draft driers (compare driers D and M in Table 41).

Moisture Content of Dried Fruits. The U.S.D.A. has placed the legal limit for moisture in dried apples at 24 per cent. In order to have a careful check on the moisture content, it is highly desirable for every plant to make frequent moisture determinations on representative samples. The official method of moisture determination consists in drying a representative sample in a vacuum oven under specified conditions to constant

TABLE 41. COMPARATIVE COSTS OF DEHYDRATION

Plant no.	Type	Fruit	Cost per green ton					
			Labor	Fuel	Power and light	Total operating charges	Fixed charges	Total cost of production
D	Air-blast tunnel, direct heat	Prunes	\$3.19	\$0.94	\$0.48	\$ 4.61	\$ 2.07	\$ 6.68
E	Air-blast tunnel, indirect heat	Grapes	4.16	2.05	0.45	6.66	2.32	8.98
H	Air-blast cabinet	Prunes	4.80	1.63	0.55	6.98	4.36	11.34
N	Ceramic oven	Grapes	4.56	1.44	0.59	6.59	13.37	19.96
M	Stack, gravity air flow	Prunes	9.75	3.26	0.20	13.21	9.68	22.89

SOURCE: After Cruess and Christie.

weight. For control purposes most plants use the Dried Fruit Association electrometric moisture apparatus, because it is very rapid and quite accurate. See Joslyn (1950) or "Official and Tentative Methods of Analysis" of the Association of Official Agricultural Chemists for further information.

Experiments have proved that most fruits containing not more than 23 per cent of moisture will keep indefinitely. Unsulfured fruits containing 25 to 30 per cent of moisture sooner or later become moldy, while those above 30 per cent soon ferment unless heavily sulfured to prevent spoiling. These limits do not hold for sulfured fruits because of the preservative action of the sulfur dioxide.

Prunes containing more than 26 per cent of moisture in most instances become moldy unless sterilized as described in Chapter 20.

Fireproof Construction. The fire risk with most dehydraters built of wood is very great, and insurance rates on such structures are high. On this account most of the dehydraters built in California in recent years have been constructed of hollow tile, concrete, or other fireproof material. Insurance may then be dispensed with, except for trays and cars.

The greater original cost of fireproof driers is compensated for within a few years by the saving in insurance cost and lower depreciation.

DEHYDRATION OF FRUITS

Dehydration affords a means of producing dried fruits of new forms and, in some instances, of better quality than is possible by sun drying. Practically all fruits can be successfully dehydrated, whereas some do not yield acceptable products by sun drying.

Preparation. Preparation of fruits for dehydration is similar to that for sun drying. A brief outline of approved methods of preparing some of the more important fruits is given below. The loss in preparing various fruits for dehydration is given in Table 42.

TABLE 42. SHRINKAGE IN THE PREPARATION AND DEHYDRATION OF VARIOUS FRUIT

Fruit	Per cent of fresh fruit unsorted					Drying ratio	
	Sorted uncut fruit	Prepared fruit cut, pitted, dipped, or hulled	Prepared and peeled fruit	Loss in preparation	Dried fruit	Gross fresh to net dry	Prepared fresh to net dry
Royal apricots.....	100.0	92.3	.....	7.7	17.2	5.8:1	5.4:1
Muir peaches:							
Unpeeled........	96.4	90.3	.....	9.7	20.9	4.8:1	4.3:1
Lye-peeled.......	96.4	90.3	86.2	13.8	19.9	5.0:1	4.3:1
Bartlett pears......	97.9	91.7	.....	8.3	19.5	5.1:1	4.7:1
Peeled..........	97.9	91.7	60.5	39.5	12.9	7.8:1	4.7:1
Grapes............	100.0	100.0	100.0	....	27.5	3.6:1	
Newtown apples....	100.0	.....	75.0	25.0	12.3	8.3:1	6.1:1
Loganberries.......	100.0	100.0	100.0	....	21.1	4.7:1	4.7:1
Cherries:							
Not pitted.......	100.0	100.0	100.0	....	33.5	3.0:1	3.0:1
Pitted and stemmed...........	100.0	80.0	.....	20.0	23.7	4.2:1	3.4:1
Raspberries........	100.0	100.0	100.0	....	14.8	6.8:1	6.8:1
Strawberries, four varieties.........	100.0	96.4	.....	3.6	16.7	5.9:1	

SOURCE: After Cruess and Christie.

Comparative Yields and Qualities of Sun-dried and Dehydrated Fruits. Accurately controlled comparisons of the sun drying and dehydration of apricots, peaches, pears, and prunes were made at the University of California. Fruit of the same condition was used for the two methods of drying, and any subsequent differences in the dried product were a direct result of the method of drying.

After drying, the fruit was again carefully weighed and representative samples were withdrawn and were later analyzed for moisture and sugar.

Consistently higher yields of dried prunes were obtained by dehydration, but for other fruits no appreciable difference in yield was noted by the two methods. The dehydrated fruits were superior in flavor and cooking quality to the sun-dried fruits, although not so attractive in appearance in some instances.

Apples. There is an increasing demand for dehydrated apples of the highest quality, although the tendency in the past has been to produce

quantity rather than quality. The cleanest, whitest fruit that is well trimmed and carefully dried and packed is most in demand. In seasons of abundant crops and low prices for fresh fruit, large quantities of apples that would normally be sold fresh are dried, and the grade of the dried product is correspondingly improved. In years of light crops, when all apples suitable for packing are in demand at high prices, only the poorer fruit is dried with, generally, a lowering of the quality of the dried fruit.

Varieties. Dried apples are graded on texture and appearance rather than on flavor. Varieties that are firm and yield a dried product of white color are therefore preferred. In California, of the commercially grown varieties, the Gravenstein and Yellow Newtown Pippin are the best for drying. In Oregon and Washington the Winesap, Jonathan, and Spitzenberg are in demand for drying purposes. The Delicious slices break badly, and peeling and coring losses are heavy. The Baldwin, Hubbardston, Northern Spy, Rome Beauty, and varieties of the Russet group are also satisfactory. The Gravenstein is one of the best of the early varieties for drying purposes. The Bellflower and some other important varieties yield dried products of yellowish color or have other defects and so are not greatly in demand for drying.

Sorting. The apples should be carefully sorted to remove rot, wormy fruit, etc., and, if possible, thoroughly washed before peeling. Sorting can be done on a broad belt.

Spray Removal. If the peels and cores are to be utilized for vinegar making, stock food, etc., the apples must be washed in warm dilute hydrochloric acid solution (1½ to 3 per cent) and rinsed in order to remove lead arsenate spray residue. If DDT residue is present, special methods must be used to remove it. Directions may be obtained from the agricultural experiment stations of apple-producing states such as Oregon, Washington, California, New York, and others. A California operator states that DDT completely disappears from the apples in the orchard before picking time, in most cases.

Peeling and Coring. Apples are peeled and cored in one operation by a machine operated either by hand or by power. The peeling is done by a guarded blade similar to a safety razor. A workman places each apple in a vertical position in the cup of the peeling machine. The cup is on a revolving arm and delivers the apple to a vertically descending fork that impales the apple and spins it rapidly. The guarded peeling knife ascends vertically and removes the peel as a ribbon. The coring knife ascends vertically and neatly removes the core. Each workman feeds two or three peelers. A belt carries the peels and cores to an outdoor hopper for later transport to a vinegar factory. The peeled and cored apples are conveyed to the trimming crew. In most drying plants, in order to facilitate trimming, the fruit is merely peeled and cored in the peeling machine and is sliced in a separate machine. A "seed-celling" attachment also is often used.

Trimming. Trimming is of great importance, because some of the peeled fruit carries pieces of peel, bruises, or portions of the calyx, which must be removed if a dried product of high quality is desired. There should be at least two workmen trimming for each workman engaged in peeling. Trimming can be done efficiently by girls or women stationed beside a slow-moving belt or at sinks supplied with fruit by a belt that passes beneath the peeling machines.

Slicing. While slicing can be accomplished at the peeling machine by means of a special attachment, it is usually delayed until after the apples have been trimmed, since trimming can be done much more efficiently with the whole, peeled fruit. The usual apple slicer is equipped with stationary blades set in a horizontal position. The peeled and trimmed apples are forced against the blades by special conveyer and are cut into rings about ¼ in. in thickness. The blades are of stainless steel or other corrosion-resistant alloy because plain steel is apt to cause staining of the apple slices by reaction of dissolved iron with the tannin of the fruit.

Small cull apples to be dried for pectin manufacture are not peeled and often are sliced into quite thin strips by means of a kraut slicer. See the chapter on pickles for description.

Sulfite Dipping. In many plants the peeled and cored whole fruit is passed through a 2 to 3 per cent bisulfite solution to prevent browning before slicing (see also next paragraph).

Sulfuring. Apples are always exposed to the fumes of burning sulfur or dipped in sulfur dioxide or bisulfite solution before drying, in order to bleach the surface of fruit that has become brown by exposure and to prevent further browning. The whole peeled fruit may be sulfured before slicing, in which case 45 to 90 min. exposure is required; or it may be sulfured after slicing, when 30 to 40 min. sulfuring will be sufficient. The fruit is either sulfured on the trays in the same manner as other fruits or may be sulfured on a wooden slat conveyer in a long chamber.

Examination of whole peeled apples sulfured in this manner will show that the sulfite has penetrated only a relatively short distance into the flesh. Consequently, additional SO_2 or sulfite treatment is needed. Practically all dehydrater operators burn sulfur on the floor of the drying kiln during the first 3 to 5 hr. of drying in order to sulfur the fruit adequately, whether or not it has been dipped in bisulfite solution or treated whole in the fumes of burning sulfur. In one large California apple-drying plant the whole peeled and trimmed apples are flumed from the trimming belt to the slicers in 3 per cent salt (NaCl) solution to temporarily arrest darkening. After slicing they are carried through a 1½ to 2½ per cent sodium bisulfite solution by a "walking-beam" conveyer. They are spread on the floor of the kiln, and sulfur is burned in a pan or in a shallow concrete hole on the floor of the furnace room beneath the kiln. The sulfur dioxide fumes rise with the heated air and increase the SO_2 content of the sliced fruit.

This initial sulfuring lasts 3 to 4 hr. It is repeated toward the end of the drying period. Before final sorting and packing the dried fruit is moistened and sulfured in the fumes of burning sulfur long enough to bring the total SO_2 content to 2,500 to 3,000 p.p.m. This is done on slat-bottom wooden trays in a tight room.

Cubing. Apples are usually cut in slices (rings) about ¼ in. thick, but a demand also exists for cubed dehydrated apples. Cubes about ½ in. in size may be cut from the whole peeled, trimmed, and cored fruit by a special machine. These dry quickly and are convenient for use in pies.

A large fruit-dehydrating company formerly operating in Oregon sliced the apples (before drying) in very thin pieces by means of a sauerkraut cutter. They may also be cut into julienne strips, in which form they are convenient for use in pies.

Driers Used. In California, apples are generally dried in kilns or on trays in a tower drier. Some are dried in modern air-blast tunnel dehydraters, in Oregon, Washington, and California. In New York and Washington the apple kiln is the customary drier. The kilns are about 20 by 20 ft. and hold about 3,500 lb. of sliced apples. They are usually equipped with fans in order to increase air flow and to shorten drying time. See Figure 91.

Temperatures. In stack driers in California a temperature of approximately 180°F. is used below the lowermost tray. In air-blast tunnel dehydraters a range of about 145 to 165°F. at the "hot end" of the tunnel is used. The lower the finishing temperature, the less is the danger of browning of the color and caramelizing of the sugar. In kilns the temperature at floor level near the end of the drying period is about 145 to 150°F.; and of the air immediately below the floor level it is usually about 150 to 160°F.

Drying Time. The drying time of apples in the stack drier is said to be about 10 to 12 hr. and in the kiln 7 to 12 hr. In the parallel-current dehydraters used in Canada it is reported that the drying time is as short as 5 to 6 hr. A temperature of 180 to 190°F. can be used at the "hot end" of the first stage.

Turning. The apples on the kiln floor are turned occasionally with broad aluminum or stainless-steel shovels during drying, to equalize the rate of drying of the apples at different levels.

Yields. In California approximately 7 tons of fresh unpeeled apples is required to give 1 ton of dry, but yields vary greatly with the variety, size, and condition of the apples.

Moisture Content. Government regulations require that dried apples contain not more than 24 per cent of moisture when offered for sale.

Storing the Dried Product. The dried apples are usually stored in bins or in heaps on the storeroom floor. Care should be taken to exclude rodents and insects. However, in the better plants it is now customary to process and pack the apples immediately after they come from the drier or dehydrater (see the section on packing dried apples, Chapter 20).

Resulfuring. Dried-apple packers moisten the dried apples and sulfur them in fumes of burning sulfur to about 2,500 to 3,000 p.p.m. sulfur dioxide content before final packaging.

Cleaning and Packing. Before resulfuring, the dried apples are screened to remove fines, seeds, etc., and are carefully sorted to remove defective pieces.

Then after moistening and resulfuring they are packed and compressed into 25-lb. boxes lined with waxed paper. Some also are coarsely ground and packed in small cellophane bags.

Apple Nuggets. Some dried apples are coarsely ground and dried *in vacuo* to bone dryness, less than 1 per cent water by the Vacu-Dry Company of Oakland, California. They are then packed in airtight containers. The Army used large quantities of these "nuggets" in the Second World War.

Apricots. Apricots are prepared as for sun drying, although 2 hr. of sulfuring is usually sufficient as contrasted with 3 to 5 hr. for fruit that is to be dried in the sun.

A temperature of less than 160°F. should be used for apricots near the end of the drying period; best results are obtained at temperatures below 150°F. Mrak and Phaff (1945) recommend that apricots be steam-blanched before sulfuring. Since any green color in the fresh fruit remains in the dehydrated, it is customary to spread the sulfured trays of fruit in the sun for several hours to bleach the chlorophyll.

Bananas. This fruit is dried to a limited extent in the tropics in driers of various types. Green fruit is peeled after loosening the skin by blanching. The peeled fruit is sulfured a short time, dried on trays until brittle, ground, and bolted to make banana flour. Ripe bananas are peeled and dried whole. These are known in commerce as "banana figs." They are of dark color and unattractive appearance but of fairly pleasing flavor. If the ripe fruit is sliced lengthwise and sulfured for 20 min. before drying, a much more attractive product is obtained.

Large quantities of bananas go to waste in the tropics in the groves and at export ports because of slight blemishes, overripeness, etc. Dehydration is a means of conserving much of this fruit and rendering it available as food.

Experiments by Mitra in the author's laboratory showed that sliced ripe bananas sulfured 15 to 30 min. before drying yield an excellent dried fruit. This procedure was, in 1946, in commercial use in Mexico.

Cherries. Cherries should be dipped in dilute boiling lye solution to crack the skins (¼ to ½ per cent sodium hydroxide) and rinsed in water.

White or pink cherries should be sulfured about 30 min. Black cherries require a short sulfuring if it is desired to retain the natural fresh color.

Cherries may be pitted before dehydration and then require no lye dipping before drying. Dehydrated sulfured-pitted cherries are excellent for pies, etc.

Figs. Whole white figs which have been allowed to ripen, to partially dry on the trees, and to drop to the ground before gathering can be dehydrated whole in 9 to 12 hr. at 165°F. Drying is much more rapid if they are cut in half. Kadota figs dry well if picked fresh from the tree before drying begins, cut in half, sulfured, and dehydrated. They also dry well whole.

Grapes. Grapes should be lye-dipped before dehydrating. Muscat and wine grapes possess tough skins and require a relatively strong solution (2 to 3 per cent sodium hydroxide), while Sultanina (Thompson Seedless) and Tokay are tender-skinned and a dilute lye solution (¼ to ½ per cent sodium hydroxide) checks the skins satisfactorily. Sulfuring has become general practice in the dehydration of seedless grapes (see below).

Grapes respond well to the two-stage system of drying, with an initial temperature of 190°F. and a finishing temperature of 160°F. in the countercurrent stage. In general practice, however, the countercurrent system is employed, with an initial temperature of 110 to 120°F. and a finishing temperature of 160 to 165°F. Dipped grapes may be dried in 20 to 30 hr. by the countercurrent system with a finishing temperature of 160°F.

Dehydrated white grapes, such as Muscat and Thompson Seedless varieties, are inclined to be more sticky on the surface than the sun-dried raisins and are usually lighter in color. So-called golden-bleach Thompson Seedless raisins are now produced in considerable quantity by lye dipping, sulfuring for about 3 hr., and dehydrating. Slat-bottom trays of 6 by 3 ft. size are used. The grapes must be thoroughly ripe in order to give raisins of satisfactory color and texture. Exposure to the sun for 1 day after sulfuring destroys any green color present. There is usually a good export demand for golden-bleach raisins.

Loganberries. This fruit was formerly dried commercially in the Pacific Northwest both in large forced-draft commercial plants and in farmers' driers of the Oregon tunnel types. No preliminary treatment, other than sorting, is necessary. However, 20 to 30 min. exposure to the fumes of burning sulfur before drying greatly improves color retention. Berries for drying should be firm-ripe, for soft-ripe fruit is apt to melt and form slabs and to lose a great deal of juice. For the same reason the berries should not be washed.

A large company formerly operating plants at The Dalles and Salem, Oregon, dried large quantities of loganberries very successfully at temperatures below 145°F. in an air-blast dehydrater.

Peaches. Peaches of canning clingstone varieties should be halved, pitted, and lye-peeled as for canning. The halves are spread on the trays, cups upward. Slat trays, heavily coated with slab oil (neutral mineral oil), should be used in order to prevent sticking to the trays. The peaches should be sulfured about 4 to 6 hr. if a light-colored product is desired. There is

also a small demand for unsulfured dehydrated peaches. Darkening of unsulfured peaches can be greatly reduced by blanching in steam on the trays until the halves are heated through to 185 to 212°F., normally for about 5 min. in live steam. Mrak and Phaff have found it is very advantageous to steam-blanch and then to sulfur in the usual manner. The dried fruit is translucent, of good flavor, and of quick-cooking quality. Some 20,000 tons of peaches was dried in this manner for the United States Army during the Second World War.

Clingstone canning varieties yield an excellent dehydrated product. Dehydrated freestone peaches, such as the Muir, Lovell, Elberta, and Crawford, are not equal in appearance to the sun-dried, although superior in flavor and cooking quality. Cling peaches have been dehydrated whole successfully after lye peeling, slitting lengthwise to the pit to hasten drying, sulfuring 12 to 15 hr., and dehydrating.

Sliced peeled clingstone peaches yield a particularly attractive dehydrated product.

Pears. Bartlett pears should be peeled and cored as for canning because the unpeeled halves prepared as for sun drying are not so attractive dehydrated as sun-dried.

The peeled halves are sulfured as described above for peaches, and drying times, temperature, and desirable relative humidity are about the same as for peaches. Pears may also be cubed, cut in julienne strips, or sliced, if desired.

Dehydrated pears are markedly superior to the sun-dried pears for culinary purposes. After 24 hr. refreshing in water, the fruit resembles the canned product in appearance and flavor (see Table 42). Recently Mrak and Phaff have found that unpeeled halved pears yield an attractive dried product if steam-blanched before sulfuring and drying.

Dehydration of Prunes in California. Prunes are prepared for dehydration in the same manner as for sun drying, although lye dipping should not be so severe because "heavy" dipping causes the dehydrated prunes to be sticky. Dipping in hot water only is now usual practice. The trays used in prune dehydraters are usually 6 by 3 ft. in size and made with slat bottoms. The dipped prunes are spread one layer deep on the trays.

Mrak and Perry (1948) have presented the various operations in preparing and dehydrating prunes with precautions that should be taken to secure a dried product of best quality. Prior to 1918 practically all prunes were sun-dried in California, whereas at present probably more than 90 per cent of the crop is dehydrated. This change in drying practice came about because of the heavy losses suffered by growers in several years of heavy, early fall rains during the sun-drying season and because the research of Christie, Nichols, Mrak, Perry, Cruess, and others of the University of California staff and Ridley, Puccinelli, and other commercial

operators and designers of dehydraters showed that carefully controlled dehydration results in higher yields of dried product and one of better cooking quality. Also, it is cleaner and prevents losses during inclement weather. Less labor is usually required in dehydration than in sun drying.

However, as Mrak and Perry indicate, dehydration cannot be expected to improve the original quality of the prunes; i.e., control of quality begins in the orchard. Prunes are usually of best quality when harvested during midseason. If left on the trees too long in certain areas, as in the Sacramento Valley in California, flesh of many of the prunes will become dark in color and gas pockets may appear; in other words, quality deteriorates seriously. On the other hand, usually the prunes picked from the ground early in the season are apt to have dropped from the tree prematurely and be somewhat low in sugar content and of poor quality when dry. In areas in which the fruit drops naturally from the tree when ripe, it should not be allowed to lie on the ground too long, as fermentation of the flesh, darkening, and gas pockets may develop. The fruit should be gathered frequently.

If the dehydrater cannot care for the prunes as fast as they are gathered, the surplus should be placed in cold storage where it will keep satisfactorily for at least a month under favorable storage conditions. Excessively hot weather may cause darkening of the flesh of the prunes on the tree with gas-pocket development. These conditions are also apt to develop if the prunes are held too long in lug boxes after picking.

At the dehydrater the prunes should be screened to remove small clods, twigs, and other debris before dipping. Also they should be washed well, either before or after dipping.

Prunes grown in California for drying are of three principal varieties, viz., the French, or Prune d'Agen, the Imperial, and the Sugar varieties. The French is a small to medium-size variety, the Imperial is of very large size, and the Sugar is intermediate in size. The latter two varieties are of delicate texture and tender skin, hence do not withstand rough handling very well.

For sun drying, as previously noted, prunes are usually dipped in hot, dilute lye solution before traying, in order to check the skins and thus hasten drying. However, it has been found that if they are dipped as severely for dehydration as for sun drying, they are apt to "bleed" (drip juice) during the initial stages of drying, making the trays and fruit sticky and causing some loss in weight. Consequently, it is now much more common to dip the French and Sugar varieties in hot water only and Imperials in cold or warm water instead of in lye solution.

After lye or water dipping they are rinsed and should then be graded roughly for size in large plants, as the small and partially dried fruit will become commercially dry more quickly than will the larger fruit. In small

plants in which all the fruit must be dried in a single tunnel, size grading may not be practicable.

In most plants the dipped prunes are spread on the trays automatically as they pass slowly by conveyer beneath exit of the dipper. However, considerable sorting is usually done as the filled tray moves to the car-loading station, in order to remove broken specimens, split prunes, and other culls.

The trays are stacked on the dehydrater cars manually by two men, although in some well-mechanized installations they are stacked by machine. If stacked by hand, the car usually rests on a platform that drops the height of one tray as a tray is placed on it, so that the workmen will not have to elevate the trays more than a few inches, if at all.

As Mrak and Perry point out, there should be a regular time interval between the entry of freshly loaded cars into the drying tunnel, as it will result in more uniform drying and quality, as well as in more orderly and regular operation of the plant. As each car of freshly dipped prunes enters the tunnel, the temperature of the exhaust air at the entry end of the tunnel drops temporarily, but usually within an hour or less rises to the previous point.

At the finishing end of the tunnel the temperature should not exceed 165°F. for the French variety and 140°F. for the Imperial. The prunes should be dried to less than 18 per cent moisture content in order that they may be stored satisfactorily. If too high in H_2O they are apt to ferment or become sticky and mat together in the storage bins. For farm storage Mrak and Perry prefer lug boxes to large bins as they are less apt to result in damage to the fruit; in deep bins the freshly dried fruit may become damaged through heavy pressure in the lower layers of fruit in the bin.

The moisture content of the dried fruit cannot be judged accurately by "feel" or appearance while it is still hot; it must be allowed to cool. Organoleptic judgment should be checked frequently by use of the Dried Fruit Association electrical-conductivity moisture tester. The California Dried Fruit Association, San Francisco, can furnish names of suppliers of this instrument.

As the Imperial variety is inclined to bleed during dehydration, special precautions may be necessary in its case. Mrak and Perry state that Imperial prunes may be spread on trays in the sun for several days, after dipping in hot water, to allow partial drying, and may then be dehydrated at not above 140°F. satisfactorily.

French-variety prunes can usually be dried in an air-blast tunnel dehydrater in 24 hr. or less; Imperials require considerably longer. According to Mrak and Perry (1948), a tunnel holding 12 cars will dry about 8 tons of fresh prunes of the French variety per 24 hr., with a similar ratio for tunnels holding other numbers of cars.

Cost of Dehydration. Christie made a survey of sun-drying yards and dehydraters and compiled the comparative costs of sun drying and dehydration as given in Table 43.

TABLE 43. COMPARATIVE COSTS OF SUN DRYING AND DEHYDRATION OF PRUNES IN CALIFORNIA ON BASIS OF GREEN TON OF FRUIT

Item	Dehydrater A	Dehydrater B	Dehydrater C	Dehydrater D	Dehydrater E	Average for dehydration	Average for sun drying
Labor	$1.90	$2.45	$2.78	$2.81	$3.42	$2.67	$3.68
Fuel	0.48	0.62	1.02	0.89	1.34	0.87	0.18
Power and light	0.65	0.65	0.74	0.86	1.03	0.79	0.04
Lye	0.04	0.07	0.08	0.15	0.07	0.08	0.09
Total	$3.07	$3.79	$4.62	$4.71	$5.86	$4.41	$3.99

SOURCE: After Christie.

Labor costs are less in dehydration than in sun drying, and the saving in cost of this item partially compensates for the extra cost of fuel and power.

While costs of dehydration are considerably higher at present, nevertheless the data given in the table are useful since they serve to illustrate the rather wide range in cost of drying that can occur in dehydraters of various types.

Yields by Sun Drying and Dehydration. Christie's experiments indicate a higher yield by dehydration than in sun drying. A ton of fruit carefully selected for uniformity of size and maturity was divided into two lots, which were further sorted into No. 1 and No. 2 fruit by a fresh-fruit grader. One lot of each grade was partially dried in the sun and stacked, and drying was completed by the most approved sun-drying methods. One lot of each was dehydrated in a commercially operated air-blast dehydrater. Samples of the dried products were analyzed for moisture content, and yields were calculated to a basis of common moisture content.

Dehydration yielded at the rate of 1,012 lb. per green ton and sun drying 969 lb., an appreciable difference in yield in favor of dehydration. The quality of the dehydrated prunes was found to be equal to, or better than, that of the sun-dried.

Dehydration of Prunes in Oregon. In the Pacific Northwest the Oregon tunnel was used for drying prunes at the orchard or in large centrally located plants owned by growers' organizations. The Italian variety, a tart prune, is grown almost exclusively. Most of this fruit is now shipped fresh or canned or frozen; relatively little is dried. In the early years of the prune-drying industry of the Northwest the Oregon tunnel was used; today air-blast tunnels are used. The Oregon tunnel is a natural-draft

dehydrater in its original design, but largely as a result of the investigations of Professor E. H. Wiegand of Oregon State College fans were installed and the efficiency of the dehydraters was markedly increased.

The dried prunes of this variety are of large size. Lewis of Oregon Agri-

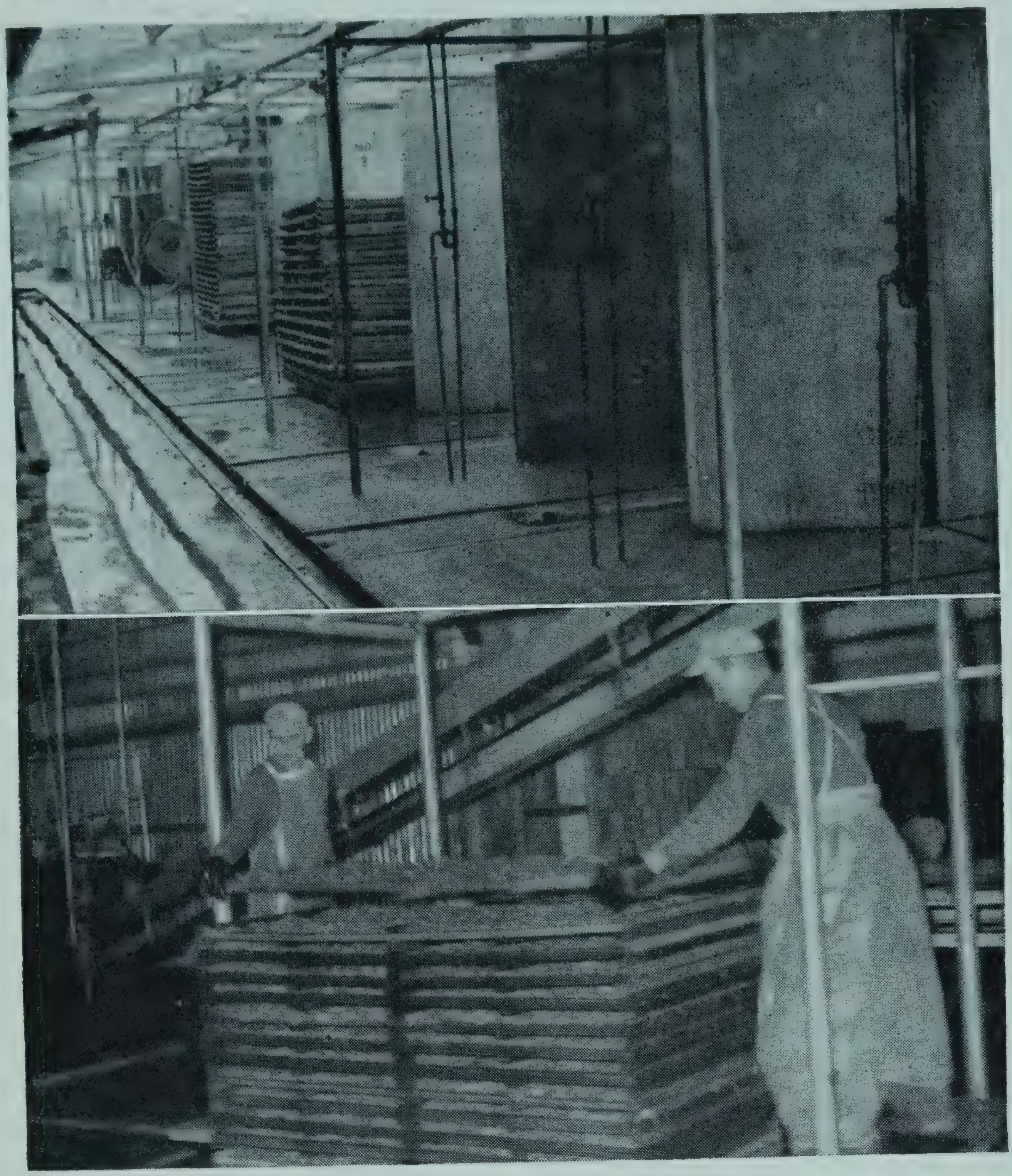


FIG. 93. *Upper:* Battery of six direct-fired, counterflow dehydraters, used for drying fruits and vegetables. *Lower:* Loading filled trays on to dehydrater car. Trays 6 by 3 ft. with slat bottoms. (*Puccinelli Dehydrater Co., Livingston, Calif.*)

cultural College (now Oregon State College) recommended that Italian-variety prunes be dehydrated to 17 to 18 per cent moisture content. They were advertised under the brand name Mistland and described in advertising as "tart sweet."

Other Fruits. Persimmons lose all their astringency ("pucker") if peeled and dehydrated, but not sulfured before dehydration; sulfuring (exposure to fumes of burning sulfur) causes them to be very astringent after drying. Evidently the SO_2 inactivates an enzyme responsible for destroying the

tannin, or pucker, during drying. They should be peeled and cut in quarters before drying. Stainless-steel knives should be used in preparing the persimmons for drying because iron reacts with the tannin of the fruit to give a black color.

Raspberries dry readily and are useful for preparing extracts or sirups. They should be given a short exposure to the fumes of burning sulfur before drying in order to prevent browning of the color.

Strawberries drip badly unless started at a fairly low temperature, 100 to 110°F. A short period of sulfuring, 10 to 15 min., greatly improves color retention.

Citrus fruits have been dried in limited quantities for use in preparing a flour or meal for flavoring purposes. The whole fruit is sliced, sulfured about 30 min., and dried bone-dry. It is then ground and is used in this form in limited amounts by bakers and confectioners. Waste orange peels are dried in rotary-drum direct-fired dehydraters for use as stock food.

Pickled ripe olives were at one time dehydrated in California but were not in great damand. If pitted before drying, ripe pickled olives yield an excellent dried product for flavoring meat dishes, etc. They possess a mushroomlike flavor. If heated in an oven after drying or if heated *in vacuo* at about 200°F., they will become plump and somewhat like popcorn in specific gravity.

Drying of Walnuts. The dehydration of walnuts has almost completely superseded sun drying. Although practiced as early as 1889, dehydration of walnuts did not come into general use until about 1920 to 1925. Present practice is based to a great extent on the investigations of Christie, Guthier, and Nichols. See Chapter 17 for methods of harvesting, hulling, and drying walnuts in the sun.

Unlike fruits, walnuts after hulling and washing are placed in drying bins rather than on trays. Warm air not above 110°F. is forced through the bins until the nuts are dry (contain less than 10 per cent moisture). Christie and Guthier showed that nuts dried at temperatures above 110°F. often became rancid in subsequent storage after drying, evidently because the higher temperatures caused some of the oil to exude to the surface of the kernels, where it later rancidified.

If the bin is deep (3 ft. or deeper), the air current should be reversed in direction at regular intervals during drying, in order to secure uniform drying. On warm, dry days, the air need not be heated, and thus fuel is conserved. Natural gas is the preferred fuel, although crude oil and other fuels are used when gas is not available. Electrical heating has been used in some cases, but its cost is excessive.

In the Brown (or University of California) dehydrater several screen floors, one above the other, are used. When the nuts on the lower floor are dry, they are removed and those from the floor above are dropped on it to

complete the drying. The nuts on the other floors, usually three in number (total of five floors for each unit), are also dropped one floor and fresh nuts are placed on the uppermost floor. Each floor is made up of narrow segments that may be tilted, thus making openings through which the nuts fall to the floor beneath. Plans and directions for building and operating this drier may be had from the Agricultural Engineering Division, University of California, Davis.

By experience the operator can judge fairly closely the moisture content of the nuts. They should be dried to about 8 to 10 per cent moisture. Usually moisture tests are made occasionally to confirm visual judgment. When the nuts are sufficiently dry, the membrane between the halves of the kernel becomes brittle. Moisture is determined by drying 50 grams of the crushed whole nuts, in an oven at 100°C., to constant weight or by distillation in a xylene moisture still, now obtainable from leading chemical-glassware supply houses (see Nichols, Fisher, and Parks).

If the nuts are overdried, they will later take up moisture in the packer's warehouse and the dehydrater operator loses the corresponding weight. Since walnuts are usually worth 25 cents or more at wholesale a pound, this loss may be appreciable. If not dried sufficiently, the nuts cannot be processed properly at the packing house, they may become moldy, or the meats may darken badly in storage.

A convenient means of bringing the nuts to the proper moisture content is to store them several days in slatted bins after removal from the dehydrater, in order to permit them to establish equilibrium with the moisture of the surrounding air.

Pineapple Dehydration. The principal outlet for pineapple grown in the Hawaiian Islands is for commercial canning as sliced and crushed pineapple, and as juice. Much smaller quantities are frozen and used in preserves and jam. During the Second World War considerable interest arose in the possibility of producing a dehydrated product for use by the military forces. At the University of California, Friar and Van Holten conducted experiments on dehydrating fresh pineapple in several forms.

The well-ripened "pines" were peeled and cored by hand, the loss in weight being about 45 per cent. They were sliced about 3/8 in. in thickness and treated in the following ways: Some slices were exposed on small dehydrater trays to a mixture of 2 per cent by volume of SO_2 gas from a cylinder of liquid SO_2 and 98 per cent air for 1 hr. and 2 hr.; some were steam-blanched on the trays for 10 min. and sulfured for 45 min.; and others were brought to boiling in a sirup of 40° Brix made of sucrose and corn sirup in equal proportions, plus water to give 40° Brix, and allowed to stand for 3 hr. before drying. All lots were dried at 150°F. in an air-blast dehydrater at 600 ft. per min. air velocity.

The various lots were sampled in the dry state and after refreshing and

cooking. The slices that were sulfured for 1 hr. without blanching were considered best in appearance and flavor after cooking; those sulfured for 2 hr. were somewhat bleached in color and tasted of SO_2 after cooking. The blanched slices were excellent in appearance and gave a somewhat larger weight on refreshing in water and cooking, but had less pineapple flavor than the unblanched fruit. The sirup-treated fruit was excellent for eating dry out of hand as a confection but was lacking in flavor when cooked. The unblanched fruit gave a drying ratio of about 6:1, and the sirup cooked 3.7:1, the greater yield in this case being due to impregnation of the slices with sugar before drying. In another experiment it was found that unsulfured pineapple darkened severely on dehydration. In general, the experiments indicated that, if need were to arise, pineapple could be dehydrated very successfully.

Dried-sirup-treated Fruits. The preparation of candied and glacé fruits is a long and costly procedure; consequently the price of the finished products is high and consumption is limited. In experiments reported by Cruess (1918) and later by Cruess, Friar, and Van Holten (1945), it was found that very attractive sugar-impregnated dried fruits can be prepared quickly and at low cost by treating the fruits in sirup before dehydration. Dried sirup-treated fruits are produced commercially in Australia.

Cherries, apricots, pears, peaches, Kadota figs, and canned sliced pineapple were used in the experiments in 1945. Those in which apricots were used will serve as illustration.

One lot of the cut and pitted apricots was exposed to the fumes of burning sulfur in a tight sulfuring box for 2 hr. Part was dried in the sun, and part in the dehydrater. Another lot was heated to boiling in 40° Brix sirup made up of corn sirup, sucrose, and water and set aside for 2 hr. before drying. Half was dried in the sun, and half was dehydrated. The lot that was dehydrated was superior to the sun-dried in appearance and flavor. The drying ratio of the untreated fruit was 5.26:1, and that of the sirup treated 3.7:1. In other tests various ratios of corn sirup to sucrose were used in making up the sirups used in the pretreatment of the halved fruit. A ratio of 1 of corn sirup to 3 or 2 of sucrose was found superior to the usual 1:1 ratio. Corn sirup or invert sirup in a ratio of at least 25 per cent by weight to 75 per cent of sucrose is necessary to prevent sugaring and excessive drying out of the dried product during storage after drying. When the whole unpitted apricots were used it was found advisable to dip them for a few seconds in dilute (2 per cent) boiling NaOH solution to check the skins slightly so that the sirup would penetrate satisfactorily.

Boiling of the fruit in the sirup before drying caused undue softening; better results were obtained by heating to 185 to 190°F. and letting stand in the sirup overnight before drying. A product closely resembling candied fruit was obtained by treating the halved apricots first in 40° Brix sirup overnight, then in 65° Brix overnight before drying.

Canned apricots, pears, cherries, pineapple, and peaches were also dehydrated, with very good results.

Powdered Fruits and Juices. As mentioned elsewhere, the Vacu-Dry Company produces dried fruit powders by first shredding the sun-dried or dehydrated fruits, then drying them under high vacuum to bone dryness and grinding the dried material to a powder in a room held at very low relative humidity. The powdered product is packed in hermetically sealed containers. It refreshes very quickly in either cold or hot water and makes a very good fruit sauce when cooked a short time in water with sufficient sugar to give a satisfactory degree of sweetness.

In experiments conducted in the writer's laboratory at the University of California it has been found that fruit powders or granules that remain stable in the open (do not absorb moisture and become sticky) can be made as follows: The sun-dried or dehydrated fruit is heated in steam until it is well softened and reaches a moisture content of 30 to 35 per cent. It is then coarsely ground and mixed with 1¼ to 2 times its weight of dry dextrose sugar. The mixture is then ground twice to produce an intimate mixture of fruit and sugar. The mixture is spread on trays and dehydrated to bone dryness at 120 to 140°F. It is then ground and screened. The powder or granules are satisfactory for cooking for sauce with water.

Recently the vacuum drying of fruit juices, concentrates, and tomato paste to bone dryness followed by grinding or crushing and screening has been done commercially as well as on a pilot scale.

L. V. Burton (1947) reported that the Vacuum Food Corporation at Plymouth, Florida, successfully produced orange-juice powder by a procedure devised and developed by the National Research Corporation of Boston. First an orange-juice concentrate was produced in a multistage, low-temperature concentrating unit at very high vacuum. The resulting concentrate was then dried in special vacuum-drying chambers at very high vacuum and low temperature to less than 1.5 per cent moisture. The dried product was screened in a room held at very low air humidity to break up any clumps of dried juice, and the dried juice was packed in cans, the lids given the first sealing operation; cans were vacuumized, and the vacuum released with nitrogen gas and the cans sealed. Burton states that the canned powder kept well at room temperature and on reconstitution with water made a very acceptable beverage. However, subsequent developments in Florida and California were in the direction of frozen orange concentrates of 42 to 43° Brix.

Recently (1955) a description was given in *Food Engineering*, New York, of a process of producing powdered orange juice developed by Strashun and others of the Western Regional Laboratory of the U.S.D.A., Albany, California, and now in use by Orange Crystals, Inc., a subsidiary of Vacu-Dry Company of California. In brief, the procedure is about as follows: First an orange concentrate of 58° Brix is prepared by concentrating juice

at low temperature *in vacuo*. The concentrate is stored under low-temperature refrigeration until needed. It is then spread in a thin layer by roller on an endless, stainless-steel belt traveling over two large drums in a large, enclosed steel tank held under very high vacuum. The belt is heated on the first drum, and as it travels in the vacuum chamber the thin layer of concentrate is dried to bone dryness. It is scraped mechanically from the belt by very sharp knives extending across and lying in close contact with the belt at the second drum, which is artificially cooled by circulating refrigerating medium inside the drum. The crystals (dried juice) are collected in a special airtight container under vacuum at the exit end of the dehydration tank. The dehydration tank, incidentally, is quite large, about 12 ft. in diameter and 50 ft. in length.

Similar procedure and equipment are now in use in a large California plant for the production of powdered tomato juice. A tomato paste is dried on a stainless-steel belt traveling under very high vacuum in a large tank similar to that mentioned above. The belt in this dehydrater is heated by infrared lamps. A dried product of deep-red color and rich flavor is obtained.

In the production of the powdered orange juice in the Florida plant previously mentioned, a dry flavor concentrate consisting of cold pressed orange essential oil entrapped in sorbitol is added to the dried powder before packaging. A desiccant, viz., lime, packaged in a siftproof but permeable envelope, is placed in each container to reduce the moisture content of the crystals to a very low value and to maintain them at low moisture. On opening the container the envelope is discarded. For use as a beverage the powder is mixed with water to give a "juice" of 12 to 13° Brix. The dried product as packaged is fluffy or puffed in appearance and porous in texture, hence reconstitutes very rapidly in water. The military has taken a considerable quantity of the crystals, and the product is also being placed on the civilian market. In comparison with the canned fresh juice the canned, puff-dried juice represents a saving of 86 per cent in shipping weight, 77 per cent in storage space, and 82 per cent in handling costs, according to the report (1955) cited earlier in this section.

Freeze Drying. Serums, vaccines, and bacterial preparations are dehydrated from the frozen state under extremely high vacuum by sublimation of the water. At very high vacuum water freezes; that fact has been made use of in producing ice. Fruits, vegetables, blood, meats, and other heat-sensitive products have been dried by this technique; and early in the investigations of orange concentrate for freezing storage in Florida, orange juice was dehydrated to a dry product, both experimentally and industrially by this process.

It has been applied experimentally by Chichester (1956) at the University of California as a means of dehydrating apricots and other fruits. The color and flavor of the fresh fruit were retained to a remarkable degree. Also,

the dried product when placed in water absorbed it very rapidly. The fruit was dried to very low moisture content and stored in tightly sealed containers in order to prevent moisture "pickup."

At present the method is too costly for the commercial drying of fruits. Whether or not it will find commercial application for this purpose is a point that will repay watching. Freeze drying is also known as lyophillization as well as sublimation drying. For a comprehensive presentation of this subject see Flosdorf (1949).

U.S. Grades of Dried Fruits. The U.S.D.A., Agricultural Marketing Administration, has established specifications for the various quality grades of sun-dried and dehydrated fruits. These are presented in Chapter 20, Packing of Dried Fruits and Vegetables.

REFERENCES

Batchelor, J. D., Christie, A. W., Guthier, E. H., and Larue, R. G.: Sun drying and dehydration of walnuts, *Univ. Calif. Agr. Expt. Sta. Bull.* 376, 1924.

Burton, L. V.: High vacuum techniques utilized for drying orange juice, *Food Inds.*, **19**, 617–622, 738, 740, 742, 744, 1947.

Carrier, W. H.: The theory of atmospheric evaporation, *Ind. Eng. Chem.*, **13**(5), 432–438, May, 1921.

Christie, A. W., and Nichols, P. F.: The dehydration of prunes, *Univ. Calif. Expt. Sta. Bull.* 404, 1929.

——— and Ridley, G. B.: Construction of farm dehydraters, *J. Am. Soc. Heating Ventilating Eng.*, **29**, 687–716, 1923.

Crafts, A. S.: Cellular changes in dehydration of fruits, *Food Research*, **9**(6), 442–452, 1944.

Croce, F. M.: Desecación de frutas y hortalizas, *Mendoza* (Argentina) *Dept. Agr. Bull.* 24, 1937.

Cruess, W. V.: Prune dehydration experiments, *Fruit Products J.*, **22**(11), 324–325, July, 1943.

———: Dehydration of fruits and vegetables, *Ind. Eng. Chem.*, **35**, 53–62, January, 1943.

———: Experiments on drying unsulfured apricots and peaches, *Fruit Products J.*, **21**(5), 135, 157, January, 1942.

——— and Christie, A. W.: The dehydration of fruits, *Univ. Calif. Agr. Expt. Sta. Bull.* 330, 1921.

———, Friar, H. F., and Van Holten, P.: Dried, sirup treated fruit, *Fruit Products J.*, **24**(8), 241, 242, 247, April, 1945.

Eidt, C. C.: Principles and methods involved in the dehydration of apples, *Can. Dept. Agr. Pub.* 635 (*Tech. Bull.* 18), 1938.

Flosdorf, E. W.: "Freeze-drying: Drying by Sublimation," Reinhold Publishing Corporation, New York, 1949.

Food Engineering Staff: Quick dries with infra-red, *Food Eng.*, **27**(6), 58, June, 1955.

Friar, H. F., and Van Holten, P.: Pineapple dehydration, *Fruit Products J.*, **24**(3), 70, 89, November, 1944.

Guillou, R.: Developments in fruit dehydrater design, *Agr. Eng.*, **23**, 313–316, 1942.

——— and Moses, B. D.: "Farm Dehydrater," University of California, College of Agriculture, Davis, Calif. Mimeographed plan.

Harper, J. C., and Tappell, A. L.: Freeze drying of food products, chap. 5, pp. 172–232, in E. M. Mrak and G. F. Stewart (eds.), "Advances in Food Research," vol. 7, Academic Press, Inc., New York, 1957.

Hausbrandt, E.: "Drying by Means of Air and Steam," Scott, Greenwood & Sons, London, 1912.

Havighorst, C. R.: One per cent moisture attained by vacuum dehydration, *Food Inds.*, **16**(4), 258–262, 1944.

Mrak, E. M., and Perry, R. L.: Dehydrating freestone peaches, *Univ. Calif. Agr. Expt. Sta. Circ.* 381, April, 1948.

———, ———, Phaff, H. J., Marsh, G. L., and Fisher, C. D.: Dehydration of fruits, *Univ. Calif. Agr. Expt. Sta. Bull.* 698, December, 1946.

Nichols, P. F., and Christie, A. W.: Dehydration of grapes, *Univ. Calif. Expt. Sta. Bull.* 500, 1930.

———, Fisher, C. D., and Parks, W. J.: Finding moisture content [of dried fruits and nuts], *Western Canner and Packer*, **25**, 11–13, 1931.

———, Moses, B. D., and Glenn, D. S.: Walnut dehydraters, *Univ. Calif. Agr. Expt. Sta. Bull.* 531, 1932.

Perry, R. L.: Heat and vapor transfer in the dehydration of prunes, *Agr. Eng.*, July, 1944, pp. 447–456.

———, Mrak, E. M., Phaff, H. J., Marsh, G. L., and Fisher, C. D.: Fruit dehydration, principles and equipment, *Univ. Calif. Agr. Expt. Sta. Bull.* 698, December, 1946.

Phaff, H. J.: Fruit and vegetable dehydration principles and advances, Biologia II, **12**, 307–329, 1948–1949.

——— and Mrak, E. M.: Sulfur house operation, *Univ. Calif. Agr. Expt. Sta. Circ.* 382, April, 1948.

———, ———, Alleman, R., and Whelton, R.: Microbiology of prunes during handling and drying, *Fruit Products J.*, **25**(5), 140–155, January, 1946.

———, ———, and Perry, R. L.: New methods produce superior dried cut fruits, *Food Inds.*, **17**, 150–153, 234, 236, 238, 516–518, 600, 602, 604, 608, 634–637, 1945.

Prater, A. N., Johnson, C. M., Pool, M. F., and Mackinney, G.: Determination of sulfur dioxide in dehydrated foods, *Ind. Eng. Chem., Anal. Ed.*, **16**, 153–157, 1944.

Proc. 1st and 2d Dehydration Convs., Calif. State Dept. Agr., Suppl. Monthly Bull., **9**(3), March, 1920; **10**(2), February, 1921.

Ridley, G. B.: Tunnel dryers, *J. Ind. Eng. Chem.*, **13**(5), 453–460, May, 1921.

Smock, R. M., and Neubert, A. M.: "Apples and Apple Products," Interscience Publishers, Inc., New York, 1950.

Strashun, S. J., and Talburt, W. F.: Orange juice powder, *Food Technol.*, **8**(8), 40, 1954.

Superior dehydrated juices from continuous vacuum process, *Food Eng.*, **27**(3), 71–74, 164, March, 1955.

Unusual convenience items are low moisture fruits, *Western Canner and Packer*, **47**(12), 29–32, November, 1955. Describes Vacu-Dry procedure.

von Loesecke, H. W.: "Drying and Dehydration of Foods," Reinhold Publishing Corporation, New York, 1943.

Wiegand, E. H.: Drying prunes in Oregon, *Ore. Agr. Expt. Sta. Bull.* 205, 1924.

———: Recirculation Dryers, *Ore. Agr. Expt. Sta. Circ.* 40, 1923.

CHAPTER 19

DEHYDRATION OF VEGETABLES

During the First World War about 9 million lb. of dehydrated vegetables, mostly potatoes and soup vegetables, was shipped to the American forces in Europe. In general, the dried products were tough and of haylike flavor, according to veterans of that war. Prescott (1919) states that dried vegetables were used sparingly by the Union armies during the Civil War and dried soup vegetables were used successfully by the British forces in South Africa in the Boer War.

During the Second World War both the German armies and those of the Allies used large quantities of dehydrated vegetables. Because of the research of the U.S.D.A., the University of California, and other agencies following the First World War, the quality of the dried vegetables supplied to the armed forces in the Second World War was much superior to that of the dried vegetables which left such unhappy memories with the soldiers of 1917 and 1918. The principal difference in technology was that at that time most of the vegetables were not blanched before drying, whereas during the Second World War all except onions were very thoroughly blanched, thus giving dried products of tender cooking character, better flavor, and better keeping quality. They were also dried to lower moisture content, and certain varieties were sulfited before drying, both treatments greatly improving keeping quality. Nevertheless, they were not equal to the fresh, and Army and Navy cooks often badly mishandled the dried vegetables in the cooking and seasoning. Hence the average "G.I." will testify that he never again wants to see, let alone eat, dehydrated vegetables of any kind, not to mention dried milk and dried eggs!

However, dehydration made it possible to provide a healthful, varied diet to the men overseas, in spite of the shortage of freighter ships. One ship loaded with dehydrated foods carried the equivalent of five or six loaded with canned and fresh foods. In other words, the 25 million to 300 million lb. of dried vegetables per year produced during the war years played a very important role in feeding the Allied land and sea forces. In addition, they were of great value in supplementing the scanty and monotonous diet of our allied civilian populations under Lend Lease.

Present Status. During the Second World War there was tremendous expansion of vegetable-dehydration facilities: many new plants were built,

and many existing fruit dehydraters were converted to vegetable drying. Since the close of the war most of these have been closed for lack of markets after termination of Army contracts. Only a few of the largest and oldest vegetable dehydraters have remained in operation in California, chiefly on products dried before the war, viz., onion flakes, onion powder, garlic powder, pimientos for making paprika powder, and hot peppers for chili powder. The demand for onions and onion flakes appears to be good.

Several companies in the Pacific Northwest are drying julienne or diced potatoes and powdered potatoes for use in preparing shoestring and mashed potatoes. Some potato flour is also probably being produced as before the war for use in bread making and for other purposes.

At the latest account (1956), at least one old-established firm was drying mixed soup vegetables, and two others were again drying various vegetables for powdering for use in pharmaceutical preparations.

Onions and garlic are dehydrated in large quantities for flavoring canned soups, canned meat dishes, various other meat products, and certain other foods commercially. Also they are used by restaurants, hotels, and other eating establishments, and some of each is used in the home. Pimientos and hot red peppers are dehydrated on a commercial scale for production of paprika and cayenne. In general there appears to be little immediate likelihood of large-scale dehydration of most other vegetables for civilian use, although the author believes that millions of housewives would use dehydrated onions because of their convenience and potent flavoring power and that dehydrated soup vegetables of high quality should find favor in the civilian market.

TABLE 44. COMPARISON OF WEIGHTS OF CANNED AND DEHYDRATED VEGETABLES; FROM 1,000 LB. OF THE PREPARED FRESH VEGETABLES*

Vegetable	Canned and packed, approximate weight, lb.	Dehydrated and packed, approximate weight, lb.
String beans	2,200	200
Cabbage	1,700	150
Carrots	1,960	200
Corn	2,000	400
Onions	2,000	180
Peas (shelled)	2,165 (No. 2 cans)	250
Potatoes	2,000	400
Spinach	1,650	155
Sweet potatoes	1,600	300
Tomatoes	1,500	85 (powdered)

* The vegetables are canned in No. 2½ cans unless otherwise indicated, and the dried vegetables are loosely packed in 5-gal. cans.

SOURCE: After Cruess and Mackinney.

In Holland, Switzerland, and Denmark before the Second World War one could see compressed dehydrated soup-vegetable mixtures in the display windows and showcases of many grocery stores. The author was told that these were quite popular.

Comparison with Canned Vegetables. Dehydrated vegetables weigh only one-fifth to one-twentieth as much as an equivalent amount of the canned. This results in a great saving in containers and shipping space. Their principal disadvantages are that they usually require a longer cooking period than the canned and do not retain their flavor and color so long as the canned in storage. In Table 44 are given the relative weights of the canned and dried vegetables from equal amounts of the fresh.

Food Value of Dehydrated Vegetables. During the Second World War studies were made in England, Canada, the United States, and Australia on the chemical composition of dehydrated vegetables and on the changes in nutritive values, particularly vitamins, during drying and storage. In Table 45 are given approximate food values for several fresh vegetables and the corresponding dried vegetables dried to 5 per cent moisture.

TABLE 45. APPROXIMATE COMPARATIVE FOOD VALUES OF SEVERAL FRESH AND DEHYDRATED VEGETABLES (TO 5% MOISTURE BASIS)

Vegetable	Per cent water	Per cent protein	Per cent carbohydrates	Fuel value per pound, calories	Ratio of fuel value, fresh to dried
Cabbage:					
Fresh	91.5	1.6	5.6	145	1:11.1
Dried	5.0	17.7	62.3	1,613	
Corn:					
Green	75.4	3.1	19.7	470	1:3.9
Dried	5.0	11.8	75.7	1,806	
Peas:					
Green	74.6	7.0	16.9	385	1:4.5
Dried	5.0	26.2	62.8	1,728	
Potatoes:					
Fresh	78.3	2.2	18.4	385	1:4.5
Dried	5.0	9.5	80.2	1,677	
Pumpkin:					
Fresh	93.1	1.0	5.2	120	1:13.7
Dried	5.0	13.6	71.1	1,643	
Carrots:					
Fresh	90.0	1.1	5.9	126	1:8.2
Dried	5.0	9.7	48.0	1,039	

Chase (1942) states that losses of ascorbic acid in steam blanching of kale, beets, potatoes, and cabbage prepared in the usual manner were 19.7, 14.8, 22.5, and 14.1 per cent, respectively, and by water blanching

were 43.6, 36.6, 37.5, and 51.5 per cent, respectively. Morgan (1944) observed smaller differences between steam and water blanching, but also found losses more severe in water than in steam blanching. Other investigators have found considerable losses of other water-soluble dietary values such as minerals, thiamine, riboflavin, other water-soluble vitamins, sugars, and nitrogenous constituents—more severe in water blanching than in steam blanching (Adam et al., 1942).

Morgan (1944) found that unblanched broccoli, peas, mustard greens, and spinach lost during dehydration 62, 64, 75, and 84 per cent, respectively, of their ascorbic acid content, whereas the blanched lost 20, 38, 52, and 70 per cent, respectively, showing that blanching exerts a strong protective action during drying. Mackinney and others have shown that sulfiting of the blanched vegetables before drying still further protects ascorbic acid during drying but unfortunately destroys most to all of thiamine.

Ascorbic acid decreases during the storage of dehydrated vegetables. For example, Chace (1942) reported that dehydrated blanched cabbage lost about one-third of its ascorbic acid when it was dried to 3.6 per cent moisture and stored 16 weeks at 90°F.; similar cabbage of 8.2 per cent moisture lost about 90 per cent of its ascorbic acid content. In nitrogen the losses were much less; similarly in carbon dioxide gas. Riboflavin losses were slight, both in air and in inert gases. Morgan stated (1944) that losses in thiamine in storage are usually slight and sometimes within the sampling and assay error. She found niacin (nicotinic acid) very stable in storage, the losses being very slight or not detectable by the usual methods of assay.

Morgan (1944) found rather severe losses in carotene during the dehydration of several unblanched vegetables, namely, 27, 50, and 26 per cent, respectively, for spinach, peas, and mustard greens, but no loss during drying of blanched spinach and peas and 20 per cent loss for blanched mustard greens. Mackinney and Cruess (1943) reported that unblanched unsulfited carrots contained after 3 months' storage at 90°F. in air only about one-fourth as much carotene as the blanched unsulfited and only one-eighth as much as the blanched sulfited samples. Various investigators found early in the Second World War that carotene is much more stable in dried vegetables stored in inert gas such as carbon dioxide than in air. Hence, Army specifications required that dried carrots and cabbage be packed in carbon dioxide gas in sealed cans.

Washing. Root vegetables require soaking and very thorough washing in order that adhering soil will not accumulate in the lye peeler or steam peeler and clog the lines. Cabbage is not usually washed, since its outer leaves are removed in preparation. Spinach requires very thorough, even

violent, washing to remove dust and insects. The same principles and methods apply as in the washing of vegetables for canning.

Peeling. Potatoes and carrots were peeled by strong lye solutions in most dehydrating plants during the Second World War in equipment similar to, or identical with, that used for the lye peeling of peaches. For carrots the usual concentrations ranged from about 5 to 10 per cent and for potatoes from about 10 to about 15 per cent. It was found that peeling losses were apt to be less at higher concentrations with potatoes, but very strong lye solutions were apt to cause pebbling and excessive loss of weight with carrots. Heating the potatoes in boiling water before they enter the lye solution hastens peeling and conserves lye.

Potatoes and carrots were also flame-peeled in one large plant early in the war. In several plants carrots and potatoes were peeled by treating with steam under high pressure in a closed vessel for a few seconds, followed by releasing of the pressure and washing under heavy sprays of water. Batch-type steam peelers were used at first, but at present a continuous steam-pressure ("steam-contour") peeler is used by some canners. Recently lye and high-temperature steam have been used together for peeling, the lye treatment being applied before the product enters the steam peeler.

Onions are "peeled" in one large plant by gas flame, which burns off or chars the outer "paper" husks. They have also been peeled by first cutting off the top and root portion of each onion and then subjecting them to a combination of heavy water sprays and rapidly revolving rubber rolls that exert a mild abrasive action. Hand peeling was also common in some plants during the Second World War.

Beets are usually peeled by first steam blanching, often under pressure, until cooked through and then slipping off the skins by hand. Abrasive peelers can also be used on the fresh beets and blanching applied after dicing or slicing. Also, steaming followed by abrasion peeling has been used successfully.

Slicing, Dicing, and Shredding. Potatoes after peeling and trimming are either cut into shoestring pieces or are diced into pieces about $\frac{1}{4}$ by $\frac{3}{8}$ in. or smaller; similarly for carrots and beets. During the Second World War some sweet potatoes were sliced about $\frac{1}{4}$ in. thick; others were cut in shoestring strips or diced.

Cabbage is cut in a cabbage shredder (kraut slicer), the shreds being somewhat wider than for kraut.

For soup mixtures the vegetables are diced or cut in smaller pieces than if they were to be used individually.

Onions are usually sliced in a special machine fitted with revolving scimitar-shaped knives, owing to the tendency of kraut slicers to clog with the outer "paper" husks of the onions.

A dicer is used for potatoes and root vegetables. Its first operation cuts the product into slices by means of circular knives. Then the slices are cut into strips similar to French-fried pieces, and finally the strips are cut crosswise to give "dice." Usually the dice are not perfect cubes but are somewhat longer than wide and often irregular in form.

Blanching. With the exception of onions, pimientos, peppers, and garlic, all the vegetables commonly dehydrated are blanched in order that undesirable enzyme action may be arrested and that the dried products will refresh more readily.

In Great Britain blanching in water appears to be preferred to steam blanching. In some cases the blanching water is used repeatedly with the purpose of building up the concentration of dissolved solids to the point where leaching losses are small, a procedure termed "series blanching." In American plants during the Second World War it was customary to blanch in live steam, either in a batch-type cabinet blancher or, as was usually preferred practice, in a continuous draper steam blancher. The continuous blanchers consisted of long, rectangular metal boxes through which the vegetables traveled on a slowly moving metal-cloth (woven-wire or door-matting) conveyer belt. Most of these were level, but some were "humpbacked," i.e., sloped upward from each end to the apex near the middle of the blancher. It was believed that the humpbacked blancher provided better steam flow with less danger of stagnant sections. However, some operators replaced their "humpbacked" blanchers with the level type, because they were less complex and were thought to give as good or better steam circulation. The length of blanching in all types of steam blanchers may be varied to suit the product.

In general, this author prefers steam to water blanching because of lower leaching losses and greater cleanliness.

The blanching period should be sufficient to inactivate peroxidase enzyme completely, except with potatoes, in which a slight residual peroxidase reaction appears to be of little consequence, and with cabbage, in which catalase but not peroxidase is destroyed in blanching.

From the blancher the vegetables fall onto trays, where they are spread by hand to give a uniform tray load; or a vibrating metal sheet at the end of the blancher automatically spreads the product and an automatic device shuts off the flow of vegetables from a hopper while the loaded tray moves forward and is replaced by an empty tray. The vibrator is known as a "syntron." The vibration or oscillation is induced by a powerful electric magnet in which the current is automatically made and broken many times a second. It is effective with diced vegetables but not suitable for onions and cabbage, which are usually spread by hand.

Sulfiting. As a result of experiments made in England, Australia, and

Canada before America's entry into the Second World War and of other experiments made at the University of California and by the U.S.D.A. early in the war, the U.S. Army specified that potatoes, cabbage, and carrots be dipped in, or sprayed with, dilute sulfite or bisulfite or a mixture of the two solutions, to retard oxidative changes in storage.

Shredded cabbage, if blanched on trays on a moving chain conveyer, was sulfited in one large plant about halfway through the blancher instead of at the exit, because Mackinney (1945) had shown that the trays then were dry and free of dripping sulfite solution. A 50:50 mixture of 0.6 per cent sulfite and 0.6 per cent bisulfite solutions gives good results, the pH value of the mixture being about 6.7. The sulfur dioxide content of the dried cabbage should be above 1,000 and below 2,000 p.p.m.

In the sulfiting of carrots and potatoes the solution was usually sprayed on the diced or stripped blanched products at the syntron spreading device at the end of the blancher. This procedure was adopted at the suggestion of the author. However, they were also treated in some plants by being conveyed through a wooden trough containing the sulfite solution (usually a solution made up of about equal parts sulfite and bisulfite). The concentration was carefully controlled by frequent analyses. Potatoes after drying should contain above 500 p.p.m. and less than 800 p.p.m.; carrots, 1,000 to 1,500 p.p.m. After refreshing and cooking the sulfited dried vegetables there is usually no noticeable taste of sulfur dioxide except to one who is very sensitive to it.

The treatment greatly prolongs the storage life of all three vegetables and protects their carotene and ascorbic acid content.

Onions have a longer storage life if sulfited, but the treatment reduces their pungency. Spinach, chard, string beans, and turnips are benefited by sulfiting. It should probably not be used for peas owing to their value as a source of thiamine, which is destroyed by sulfiting.

Sulfiting protects the vegetables against scorching damage during dehydration; hence a much higher temperature can be used with sulfited vegetables than with unsulfited (Friar and van Holten, 1945; Cruess, Friar, and Balog, 1943).

Trays. Some plants used galvanized screen trays during the Second World War. These proved satisfactory even when sulfiting was applied, provided the pH value of the solution was approximately 7.0. Most California and Idaho plants, however, used trays made of wooden strips with heavy cleats at the ends and across the middle of the trays. These trays were usually 3 by 6 ft. Double strips (one on top, one on bottom) across the middle of the tray, of such thickness that the top strip of one tray rested against the bottom strip of the one above it, prevented sagging of the trays. The sides of the trays should be open to allow free air flow.

FIG. 94. Sorting, shredding, and traying vegetables for dehydration. (*Anabolic Food Products Co., Glendale, Calif.*)

The surface of the tray should of course be made of planed strips to reduce the splinter hazard; in scraping an unplaned surface, splinters peel off into the dried product.

Tray Load. For potatoes and carrots the tray load varies from about ¾ to 1½ lb. per sq. ft., and for cabbage it is about 1 lb. per sq. ft. Other diced or sliced vegetables would be loaded about like potatoes and carrots, and leafy vegetables about like cabbage or somewhat less per square foot. Too heavy loading results in slow and uneven drying and danger of scorching. Even spreading is extremely important because with uneven spreading large lumps of product may remain wet long after the balance of the product on the tray is well dried.

Drying Temperatures. If the parallel-countercurrent, two-stage method is used, most vegetables may be started in the parallel section of the dehydrater at 190 to 200°F., as the rapid evaporation of water cools the product below the cooking or scorching point. Near the end of the drying period, however, i.e., in the finishing end of the countercurrent section of the dehydrater, much lower temperatures are usually necessary. For unsulfited cabbage the temperature should not exceed 140°F.; for onions, 135 to 140°F.; for sulfited cabbage and potatoes, 165°F.; for unsulfited potatoes, 150°F. (preferably not above 145°F.); for carrots, not above 175°F. (sulfited). In general, sulfited vegetables will stand up to

160 to 165°F. safely, while the unsulfited usually (carrots excepted) will not withstand temperatures at the finish of drying above 150°F.

Vacuum Drying. During the Second World War several plants were equipped with expensive vacuum driers using trays resting on runways in a heavy boiler-plate compartment, connected to a vacuum pump and condenser. The trays were heated by steam shelves or by electric grids. Costs were high, and quality of products seen by this author was not appreciably better than that of similar products dried in a current of heated air. For products of very delicate flavor vacuum drying has a place, but the author advises caution in using it for vegetables.

Moisture Content. In the First World War it was thought that if the vegetables were dried to below 10 per cent moisture they would keep well. However, the work of Nichols, Gross, and others shortly after that war, and the work British scientists and those of the U.S.D.A. and others in 1940 to 1945, showed that they should be dried to as low moisture content as compatible with good quality. This means below 5 per cent moisture for most products, as determined by drying a 2-gram sample in a vacuum oven 6 hr. at 70°C. The sample is ground to pass a 20-mesh sieve. See *U.S. Department of Agriculture Miscellaneous Bulletin* 540 (1944) for further information on the method.

Enzyme Tests. Various methods of testing for catalase and peroxidase activity have been used. In the author's laboratory about 2 grams of the well-mixed, coarsely broken sample is placed in a large test tube with 20 cc. of distilled water. After about 15 min. soaking there is added about ½ cc. of 0.5 per cent hydrogen peroxide solution. If catalase is still active, a fairly vigorous evolution of oxygen gas will ensue within 2 or 3 min.

For peroxidase a similar sample is set up, and to it after 15 to 20 min. soaking are added ½ cc. each of 0.5 per cent hydrogen peroxide and 0.5 per cent guaiacol solution in 50 per cent alcohol. If the pieces remain unchanged in color for 15 min., the test is considered negative, or at least the blanching is considered adequate. If the pieces show a reddish or reddish-brown color within 3 min., the test is quite positive.

For cabbage it is customary to blanch only enough to destroy catalase, because blanching sufficiently to destroy peroxidase adversely affects the color of the dried product. Some laboratories use rather a large sample of potatoes in a 400-cc. beaker and count the number of pieces that show a positive peroxidase reaction per 100 pieces. Carrots and sweet potatoes should be negative for both catalase and peroxidase. Owing to substances other than peroxidase that are capable of producing a "positive" peroxidase test, the test is not reliable with all products. Balls (1943) reported data which indicate that peroxidase may be regenerated in certain vegetables (cabbage and rutabagas) after its "destruction" by heat. This may further complicate the test. Owing to the orange color of carrots some prefer to

use a 0.5 per cent solution of benzidine in 50 per cent alcohol instead of guaiacol solution for this vegetable.

Drying Ratios. The drying ratio is expressed in two ways, viz., as the ratio of the raw vegetable as received to the dried finished product, and as the ratio of the prepared raw product on the tray to the finished dried product. For potatoes it is apt to be about 8 or 10:1 for unpeeled fresh to finished dry and about 5 to 6:1 for the prepared fresh to the finished dry. The dehydrater operator is interested only in yield of finished dry per 100 lb. of unpeeled as received, whereas the experimenter is more interested in the ratio of prepared fresh to finished dry. About 15 lb. of unpeeled carrots as received and about 18 to 20 lb. of cabbage as received are required to make 1 lb. of dry; while for prepared carrots and cabbage only 10 lb. and about 14 lb., respectively, are needed to make 1 lb. of dry.

On the basis of the ratio of the prepared to the finished dry, the following are approximate yields or ratios for several other vegetables: onions about 8 to 10:1, corn about 3:1, peas about 4:1, pole string beans about 11:1, spinach about 15:1, bush string beans about 7:1, sweet potatoes about 4:1, and beets about 10:1.

Refreshing and Cooking Ratios. Dried vegetables, like dried fruits, do not return to their original fresh size and weight on refreshing in water and cooking. In experiments made in the author's laboratory, results such as the following were obtained: 10 lb. of fresh beets gave 1 lb. dry, which on refreshing in water overnight gave 5.5 lb. and on cooking 6.5 lb.; 14 lb. of fresh cabbage gave 1 lb. dry, 5 lb. refreshed, and 8.1 lb. cooked after refreshing; for onions the values were 9, 6.6, and 6.5; for corn, 3, 3.2, and 3.4, showing a greater refreshed and cooked than original fresh weight; for potatoes, 5.2 fresh, 3 refreshed, and 4.8 cooked; for sweet potatoes, 4, 3.6, and 4.1 lb.; spinach 15, 5, and 6.3; for pole string beans, 11, 4.5, and 5.7 lb.; and for tomatoes, 15, 6.5, and 7 lb.

These ratios will vary considerably with the maturity of the vegetable and even more with its variety and location where grown. The method of refreshing and cooking will also affect the results. Corn and sweet potatoes "came back" on final cooking to more than the original fresh weight, whereas tomatoes attained less than half the original fresh weight.

DEHYDRATION OF VARIOUS VEGETABLES

In order that the description of the preparation and drying of the more important vegetables may be as complete as space permits, the following additional information is given.

Potato Flour for Use in Baking. In preparing potato flour by the flake process for use in baking, the following steps are involved:

The potatoes are first washed thoroughly. They are then peeled mechani-

cally or with lye and trimmed by hand, if they are to be used for the best grade flour, although peeling is sometimes omitted. They are cooked in a retort under 15 lb. steam pressure for 15 to 25 min., which reduces them to a mealy consistency. They are then passed between steam-heated steel cylinders, which have a smooth surface and revolve closely together. Steam at about 60 lb. pressure is used in the cylinders. The potatoes are compressed to a very thin layer and dried bone-dry by contact with the hot surface of the cylinders. Mechanical scrapers remove the dried product, which falls in flakelike form to a conveyer. The flakes are ground at once and bolted to yield a flour which compares favorably with wheat flour in food value, although it is somewhat lower in protein. ?

The flake process is used extensively in Europe, but there are only a few plants in America.

Flour from Sulfured Potatoes. In a California plant during the First World War the following method was used in drying potatoes for flour for use in the textile industry. The potatoes were soaked to loosen adhering soil and then thoroughly washed, abrasion-peeled, and sliced mechanically. The sliced potatoes were sulfured in the fumes of burning sulfur on a wooden slat conveyer in an enclosed rectangular box and were then spread and dried ~~at 200~~°F. on the belt of a three-conveyer air-blast dehydrater. The dried pieces were then ground and bolted.

Prescott and Mangels attempted to prepare sweet-potato flour by the flake process but found that it was hygroscopic and soon became lumpy and of little value as flour.

Dehydration of Potatoes for Table Use. The following procedure is based on methods in use during the Second World War in California and Pacific Northwest plants.

The preferred variety in the West is the Netted Gem (Russett Burbank); second choice is the White Rose. Other varieties are used in Maine and the Middle West. From 100 lb. of potatoes as received there is obtained from 8 to 12 lb. of dried product. Loss in preparation is about 30 to 40 per cent, depending on the condition of the potatoes and the methods of peeling, etc.

In California plants the potatoes are peeled in a continuous tank and draper-type lye peeler containing a lye solution of 10 to 15 per cent sodium hydroxide. They are then vigorously washed in a rotary washer under very high-pressure sprays of water. They are then trimmed by hand at a slowly moving wide rubber belt. Trimming losses may be 10 to 20 per cent. Trimmings are valuable for feeding livestock.

Browning is rapid but can be prevented by immersing the peeled potatoes in a 0.5 per cent bisulfite solution before trimming or by precooking the unpeeled potatoes for about 14 min. in live steam before lye peeling.

The trimmed potatoes go to the dicer, which cuts them into julienne strips about $\frac{3}{16}$ by $\frac{3}{16}$ in. in cross section or into diced pieces about $\frac{3}{16}$ by $\frac{1}{4}$ in. They are then steam-blanched on a door-matting or woven-wire conveyer in a steam box for about 6 to 7 min. In the last section of the blancher they are sprayed with cold water, chiefly in order to remove

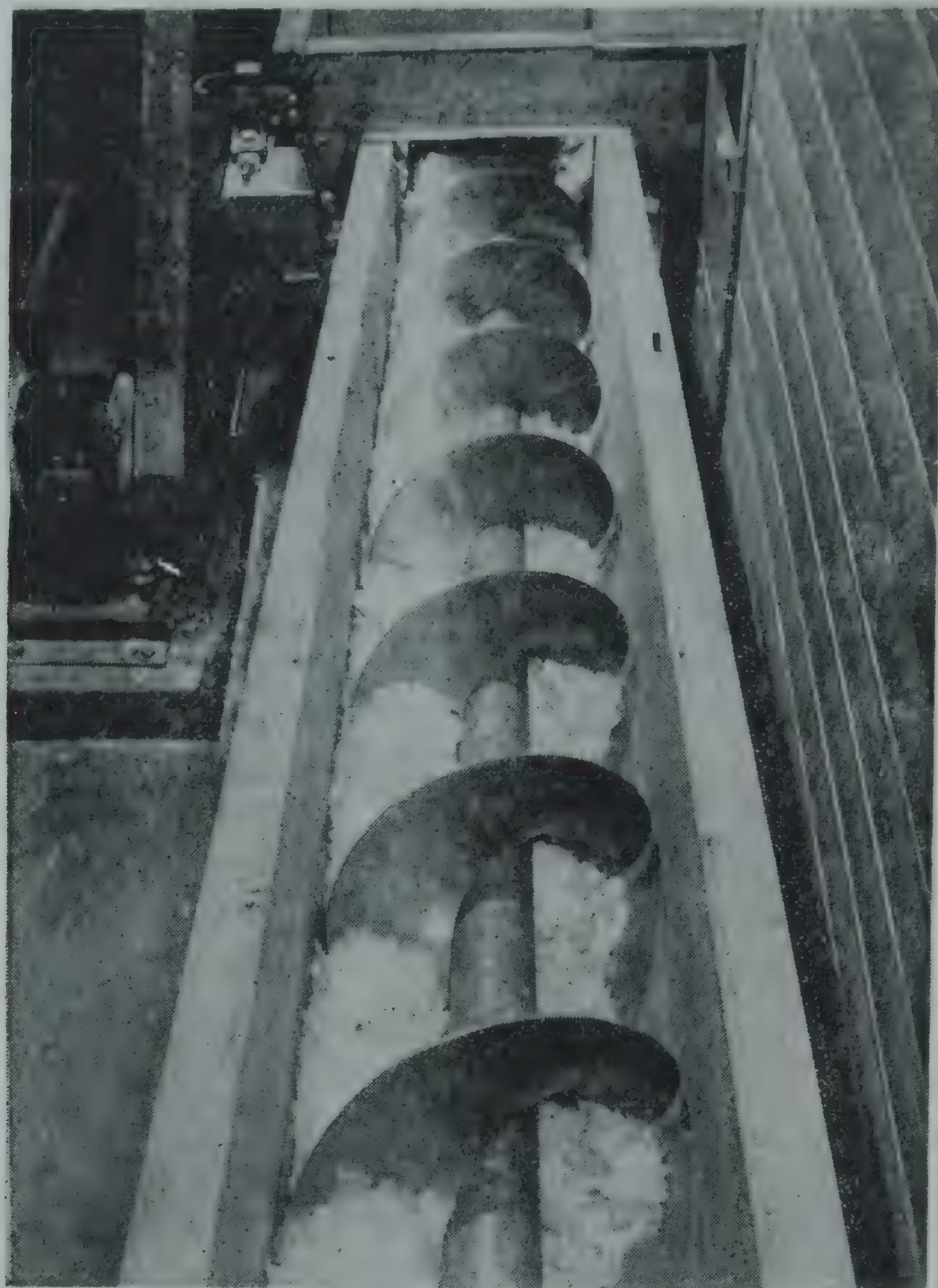


FIG. 95. Helicoid screw conveyer or augur conveyer, with lid removed for photo. (*Link Belt Co., Chicago.*)

gelatinized starch. As they emerge from the blancher they are usually spread on the trays by a syntron vibrating spreader. As they traverse the syntron they are wet with a dilute (about 0.3 per cent) sulfite solution containing equal concentrations of sodium sulfite and sodium bisulfite. They are spread on the trays at about 1 lb. per sq. ft. The trays are stacked on dehydrater cars.

They may then enter the first section of a two-stage dehydrater at 190°F., where they may remain for about 2 hr., moving progressively toward the outlet and losing in this tunnel more than half their original

moisture content. They enter a countercurrent tunnel at about 125 to 130°F. and progress slowly to a finishing temperature of 145 to 150°F. They are dried to below 7 per cent moisture. Or they may enter a countercurrent tunnel directly, in which case they are apt to start at about 120° or less and finish at 145 to 150°F. They may be removed before drying is complete and drying completed in bins at about 120°F.

Under commercial conditions the drying time may be as short as 8 or as long as 18 hr. It will depend upon the length of the tunnel, i.e., the number of carloads per tunnel; whether or not parallel current is used as a first stage in the drying process; the tray load; the air velocity; and the air temperatures. The dried potatoes are sorted carefully on a slowly moving belt before packaging.

The dried product should be analyzed for sulfur dioxide content, which should be above 500 and less than 800 p.p.m., and for moisture content, which should be less than 7 per cent. Not more than 10 per cent of the pieces should show a positive peroxidase reaction. The color should be white or very light yellow, not reddened or brown.

Riced Potatoes. In the Pacific Northwest some riced potatoes formerly were dried; large quantities were used by the armed forces during the Second World War. The peeled, trimmed potatoes are cut in pieces about 1 in. thick and are then cooked on a wire-cloth conveyer in steam for about 20 min. They are then "riced" in a machine consisting of an outer metal cylinder perforated with small countersunk holes. Inside this cylinder is a smooth smaller cylinder extending the length of the larger cylinder. Both cylinders revolve, catching the cooked potatoes between them and forcing the mashed product through the holes in spaghettilike strings onto screen trays. After drying to about 3 per cent moisture, the "spaghetti" is broken into short pieces and packed for use in making mashed potatoes.

Dried potatoes, like other dried vegetables, should be packed in moistureproof containers.

If the blanched potatoes are frozen before grinding and drying, the dried product reconstitutes much better for preparation of mashed potatoes. The final product is mealier and less sticky than that made in the manner followed during the Second World War.

Potato Granules (Dehydrated Mashed Potatoes). Potato granules, or dehydrated mashed potatoes, are the precooked, dehydrated potatoes in the form of fine granules of about 70 mesh. They consist largely of separated, whole tissue cells. On reconstitution with hot water or hot milk a product closely resembling freshly prepared mashed potatoes is formed, provided the various steps in the process of manufacture have been properly conducted.

As indicated by Neel et al. (1954), the preferred process of manufacture

is the one known as the "add-back method." It consists of the following operations: Potatoes of high solids content are washed, peeled, trimmed, sliced, cooked in steam until well done, and mashed in such a manner that the individual cells are not ruptured; the resulting wet mash is mixed with previously dried granules in the ratio of 15 parts by weight of wet mash to 85 parts of the dry in order to reduce the moisture content to 35 to 40 per cent necessary for granulation; the mix is allowed to stand for a short period to "temper" and permit equalization of the moisture content; it is mixed in a secondary mixer to induce granulation, dried by flotation in a stream of heated air (pneumatic dehydration) to about 12 per cent moisture, and transferred to a second drier and dried to 7 per cent moisture. The product is then screened on a coarse screen to remove bits of dried skin, etc., and then screened on the 70-mesh screen. What passes the 70-mesh is taken as the finished product. Of this 15 per cent may be packaged and 85 per cent recycled as outlined above.

If very many of the individual cells are ruptured, starch is released and the final product on reconstitution is sticky. It is on this account that most other methods of manufacture have been discarded in favor of the add-back procedure.

Peeling can be omitted if after dehydration the dried material is coarsely screened, as on a 20-mesh screen, to remove bits of dried peel and other coarse material.

The dehydrater used is generally of the pneumatic, conveying type. Neel et al. state that it consists of a device for dispersing the moist material into a stream of heated air, a duct, or other enclosure through which the air conveys the granules as they dry, and a means of separating the dry granules from the air stream. A cyclone separator is generally used for this separation.

If the product is to be dried to 7 per cent moisture content as specified for military use, two-stage drying is recommended by Neel et al. However, only 15 per cent of the material from each cycle need be dried to this low moisture content for packaging, since the remaining 85 per cent is recycled. A continuous fluidized, bed-type dehydrater is recommended by the authors for the second stage of drying.[1]

Olson and Harrington (1951) have described several other methods that have been used for the production of dehydrated mashed potatoes but which have been replaced almost completely by the add-back procedure outlined in this section (see references for citation of their paper).

Sweet Potatoes. During the Second World War large amounts of sweet potatoes were dehydrated for use by the military forces. It is said that much of the pack was used in making "pumpkin" pies. The dried product is excellent for most purposes for which sweet potatoes are used in the home and is also satisfactory for making open-face pie.

[1] See *Food Technology*, **8**(5), 230–234, 1954, for description of drier and other details.

They are peeled raw in abrasive peelers or are lye-peeled in 15 to 20 per cent sodium hydroxide lye solution or steam-pressure-peeled as outlined for white potatoes. After thorough washing to remove lye and disintegrated peel, etc., they are trimmed. They are then sliced or cut into julienne strips or diced. They are thoroughly steam-blanched (about 7 min.), trayed, and dehydrated at not above 160°F. to less than 7 per cent moisture. Sulfiting will prolong their keeping quality, but it was not used commercially during the Second World War.

The tray load is about 1 to 1½ lb. per sq. ft.; the drying ratio is about 4:1 on the basis of the prepared fresh to finished dry.

The Puerto Rico type of sweet potato with orange-colored flesh (often miscalled "yam") was preferred in the author's experiments to the Jersey type with its light-yellow flesh.

Arthur and McLemore (1955), reporting on experiments conducted at the U.S.D.A. Southern Regional Laboratory, found that the changes in chemical composition during dehydration—without preheating, with preheating at 130 to 140°F. for 30 to 40 min., and with preheating at 165°F. for 10 to 20 minutes, in combination with drying at initial temperatures of 200, 175, and 150°F.—do not indicate any one combination of conditions to be materially superior to the others mentioned. The results indicated that satisfactory dried products could be made by several of the combinations of conditions investigated. There seemed to be no marked superiority in behavior of any one of the four commercial varieties of the yellow, moist type of potatoes compared. If a freshly dehydrated product of highest possible carotene content is desired, the Goldrush variety is recommended by these investigators. They give details of methods of analysis for ascorbic acid, carotene, sugars, sulfite, peroxidase activity, and extractable color. In their experiments the drying ratios (pounds of raw material required to make 1 lb. of dry) varied from 5:1 to 6:1. On a moisture-free basis the total sugar content of the dried potatoes ranged from 28 to 47 per cent and the reducing sugars from 14 to 25 per cent. Carotene content ranged according to variety from 172 to 545 p.p.m., and ascorbic acid from 40 to 88 mg. per 100 grams; both reported on a moisture-free basis.

Losses of weight in lye peeling ranged from 20 to 34 per cent, with most of the values in the 26 to 29 per cent range.

Onions. Varieties of pure white flesh and high pungency are preferred. Drying ratios vary greatly with variety. The Southport White Globe, the Ebenezer, and the Louisiana Creole are characterized by good to high pungency and good yields of dried product per 100 lb. of fresh.

During the Second World War large quantities of onions were dehydrated for use by the military forces. Considerable quantities are at present dried for the military; but there is also a large demand for dried onions in sliced (flaked) form for use by restaurants and other large users and for the

powdered and so-called "free-flowing" (fine, granular) onions for the flavoring of meat products and canned soups and for eating establishment and household use.

The onions in California are grown under irrigation, many of them in the delta area of the San Joaquin–Sacramento Valleys, the Southport White Globe variety being preferred. They are dug after they have matured, and the tops are removed in the field. They are delivered to the dehydrater in sacks holding about 100 lb. each or in bulk tote bins. They may be stored for several months in a well-ventilated building or in a shed with open sides. The sacks or slatted crates or bins should be elevated several inches above the floor for good ventilation.

It is customary to first dry the whole onions slightly by a current of air at atmospheric temperature, if in summer or early fall, or by air heated to about 90 to 100°F., if in winter. The purpose is to facilitate flame peeling. The preliminary air drying of the whole onions is done in the bags.

They are then conveyed through a chamber filled with natural-gas flame, the flame being directed downward through the layer of moving onions. The flame treatment is brief. The onions are then washed in a brush spray washer to remove charred roots, tops, and paper husks. Next the root base and top of the onion are removed by a device known as a Hydrout. For onions a revolving curved blade is used in the machine. Formerly this operation was done by hand with a short-bladed knife. The flame treatment chars the roots, tops, and outer "paper" husks, although it does not completely peel the onions.

The trimmed onions are washed and then sliced by machine with revolving knives of special design, as clogging occurs if a slicer of the type used for cabbage is employed. The slices are about ⅛ in. in thickness and are spread on 6- by 3-ft. trays with wooden slat bottoms. Spreading is done by automatic equipment, the tray load being about 1¼ lb. per sq. ft. The trays are stacked on low frame dehydrater cars, 25 trays per car.

The dehydration in one California plant is in a one-stage dehydrater, a single tunnel in which the cars progress from the cooler end to the finishing, i.e., the hot-air intake end of the tunnel. In another plant a two-stage system is used. The trays are held in a primary tunnel for about 1 to 1½ hr. at about 200°F. Drying is very rapid, and because of the consequent evaporative cooling no damage to quality results. They are then transferred to a second tunnel in which a final, or finishing, temperature of about 130°F. is used. Onions, as they become nearly dry, are very sensitive to high temperature. They leave the second tunnel at 6 to 7 per cent moisture content, on the average, some slices being considerably above this level and some below it.

The onions are next transferred to finishing bins in which they form a bed several feet deep. Air at 110 to 120°F. is blown upward through the onions

and gradually reduces the moisture content to about 3.5 per cent. They may then be passed between revolving metal rolls to give flakes and are screened to remove fines (small broken pieces); or they may be screened without rolling. In either case the larger pieces held by the screen are sorted on a slowly moving belt to remove pieces that have become brown during drying. For some users the circles (rings) and flakes or larger broken pieces are blended and packed in No. 10, hermetically sealed cans. For large users such as the meat-products industry or soup producers they may be packed in large steel drums. A No. 10 can will hold about 1¾ lb. of the circles and large pieces.

The smaller broken pieces, and in case of demand much of the dried product in larger pieces, goes to the free-flowing granule and powder department where they are hammer-milled or ground. The milled or ground onions are sieved over several screens to give a powder of about 80 mesh and a coarser but still fine-grained, granular product called free-flowing powder or granules. The coarser material held by the last screen is reground and rescreened.

As reported by C. R. Havighorst (1955), onions are dehydrated in one large plant in California in a continuous, three-stage dehydrater. The drier is 247 ft. long. The conveying belts inside the drying tunnels are of perforated stainless steel and are 14 ft. wide. The flow sheet is about as follows: The onions of the White Globe variety are received in bulk and stored under well-ventilated conditions. They are mechanically cleaned and graded for size. They are flame-peeled in a continuous natural-gas-heated chamber at about 2000°F. They are next brush-washed in sprays of water, trimmed by Hydrout trimmer as previously described, washed, inspected, trimmed if additional trimming is needed, sliced in a rotary slicer, spread automatically on the slowly moving conveyer of the first-stage tunnel, and subjected to about 180°F. initial temperature in a strong current of air heated by natural-gas flame. The onions as they emerge from the first stage are mechanically loosened and automatically spread on the conveyer of the second stage, and this procedure is repeated for the third stage, in which the finishing temperature is 130°F. They emerge at about 15 per cent moisture from the third stage, and drying is then completed in metal bins at 120°F., the final moisture content being less than 4 per cent. The air used in bin drying is dehumidified in a continuous regenerating silica-gel dehumidifier. All stages of the continuous dehydrater and the finishing operation are controlled in respect to temperature by automatic instruments. The dried product is separated into several sizes by screening and air classification, inspected, and sorted.

Since trays and trucks are eliminated in this plant labor costs are considerably reduced in comparison with drying in a conventional tray and truck tunnel dehydrater, according to Havighorst.

The outer paper husks that may travel through the dehydrater with the sliced onions can be removed after dehydration by an air-blast cleaner similar to the clipper cleaner used for peas for canning or freezing. In preparing the onions for drying for some purposes a mechanical trimming machine can be used that trims off the root end and the top of each onion. The knives in the slicing machine must be sharpened frequently since they must be razor-sharp to do a clean job of slicing.

Some dried onions are toasted slightly for use in making soup. If dried onions in flake or circle (ring) form are to be used for frying, they should be soaked in about 6 to 7 parts of water by weight until well plumped, usually about 2 hr. The powder or even the larger pieces such as rings may be added dry to a pot of vegetables and meat for stew at the beginning of the cooking process and will absorb sufficient water during cooking. Also, the powder or the fine granular free-flowing product may be added directly to stews, soup stock, salad dressing, etc.

The *U.S. Department of Agriculture Miscellaneous Publication* 540 reports that the drying ratio of onions ranges from 3.2:1 to 20.0:1 (pounds of fresh to produce 1 lb. of dry), with an average of 7.6 to 9.4:1. Cruess and Mackinney in the *University of California Bulletin* 680 state that the average drying ratio in their experiments was 9.1. It varies greatly with the variety of onion and growing conditions.

Dehydrated onions are, under most climatic conditions, hygroscopic and will absorb moisture. It is therefore necessary to pack them in air tight containers. Also, they are very fragile and easily broken, hence have to be handled carefully in the plant after drying.

Treatment in SO_2 fumes or dipping the sliced onions in dilute bisulfite solution before drying greatly improves the color of the finished product but damages flavor and "aroma," hence this treatment is seldom used. The maximum moisture content of dehydrated onions has been established at 4 per cent.

Carrots. In California the Imperator variety has given better drying ratios and higher yields of dry to fresh than the Red Cored Chantennay, the other principal variety grown commercially in that state. However, both varieties are satisfactory. Other good varieties are Danvers Half Long, Morse Bunching, and Nantes. The Chantennay is apt to develop a green top section and green core. It also seems more susceptible to pithy or hollow core than is the Imperator.

Carrots are grown and harvested mechanically and delivered to the dehydrater in portable bins, sacks, or lug boxes. As they carry adhering mud or soil, thorough washing is necessary before they enter the lye peeler, in order not to load it with mud. The carrots usually first go through a dry cleaner, a revolving screen or vibrating flat screen or brushes that remove much of the loose soil. They then are washed in a rotary drum in heavy sprays of water.

Next they are lye-peeled as described for potatoes, except that the lye solution is usually weaker, normally 5 to 10 per cent sodium hydroxide. They are then washed in a drum spray washer or in two of them in series, to remove lye and disintegrated skins.

Beyond the washer the carrots are trimmed by women working at a broad rubber belt. The taproots and green portions at the top of the carrots are trimmed off together with any seriously blemished or unpeeled portions. There is much less trimming than for potatoes.

They are then cut into julienne strips or dices of about the size and in the manner described for potatoes; dices were preferred by the Army, as a greater weight could be packed per 5-gal. can than of julienne strips.

The next operation is steam blanching for at least 7 min. to completely inactivate peroxidase and other enzymes. As the carrots emerge from the blancher and pass over the syntron or similar spreader, they are sprayed with a dilute solution of sulfite-bisulfite of such strength that after drying, the carrots will contain 1,000 to 1,500 p.p.m. of sulfur dioxide.

The tray load is about 1 to 1½ lb. per sq. ft. If two-stage drying is used, the initial temperature may be 185 to 200°F., and the finishing temperature is 155°F. in the secondary tunnel. By two-stage drying it is possible to dry carrots in 5 hr. Countercurrent single-stage drying takes about 9 hr. in efficient tunnel dehydraters.

The carrots should be dried to about 10 per cent moisture and then transferred to portable finishing bins in which dehydration is completed at about 120°F. However, fairly satisfactory results are obtained by completing the drying process on the trays at 155°F. They should be dried to less than 5 per cent, preferably less than 4 per cent, moisture, since the lower the moisture content, the better the keeping quality and retention of carotene.

They should be packed in airtight containers, which should first be evacuated and then filled with carbon dioxide gas. For military use they were packed in 5-gal. cans that were sealed by double seaming in much the same manner as small cans of other foods.

Before packing, however, the dried carrots are carefully sorted on a slowly moving belt to remove discolored pieces and other cull material. Carrots affected with pithy core will yield many white pieces that must be sorted out after drying.

Pumpkin. Pumpkin and squash have been dehydrated for the preparation of "pumpkin flour," a finely ground, coarsely bolted mixture of the two vegetables. In California a mixture of Connecticut field pumpkin and Boston Marrow squash was used when pumpkin flour was made commercially.

The pumpkins and squash were cut in half with large knives, and the seeds and seed-cavity pulp removed. The unpeeled halves were sliced or shredded in a silage cutter or other heavily constructed cutting machine

into pieces about ¼ in. thick. In most factories the pumpkin and squash were not blanched, but the color is greatly improved if the slices are steamed on the trays until heated through.

The vegetables were dried to less than 6 per cent moisture and were ground in an attrition mill or hammer mill before they could absorb moisture and become leathery. The ground product was bolted or screened to remove the coarse particles, which were reground. The resulting flour was packed in small envelopes for household use or in large friction-top cans for bakery, restaurant, and hotel use for pies. Canned pumpkin has replaced the dehydrated.

Tomatoes. Tomatoes may be dried in sliced form unpeeled, but the quality is much improved by peeling before drying in the same manner as for canning.

Slices should be about ¼ in. thick. No blanching is required.

Temperatures below 150°F. should be used, as the slices darken at higher temperatures. They should be dried until the pieces show no moisture when pressed between the fingers, or until the slices will break crisply on bending. The color is improved if the sliced tomatoes are sulfured in the fumes of burning sulfur for 20 to 30 min. before drying.

The dried product may be packed in the form in which it comes from the trays; it may be ground to a meal which can be used in soups, etc., without preliminary soaking, or the ground product may be pressed into bricks. The drying ratio is about 16:1.

A short exposure to sulfur dioxide fumes on the trays before drying aids in color and vitamin C retention, also in prolonging the keeping quality. Tomato purée may be concentrated in a vacuum pan to a heavy consistency and then dried to flakes on a drum drier, preferably *in vacuo.*

Kaufman, Wong, Taylor, and Talburt of the U.S.D.A. Western Regional Research Laboratory have reported (1955) on successful experiments in the production of tomato-juice powder by vacuum drying. It was found that if concentrated tomato juice (tomato paste) of high solids content was dried under vacuum, a dense dried product that reconstituted very slowly in water was obtained. If, however, the tomato juice before any concentration had taken place were centrifuged to obtain a pulp-free serum and a pasty solids fraction, a puffed friable powder could be obtained by the following procedure: The serum fraction is concentrated by vacuum pan to 60 per cent soluble solids. It is then placed on the hollow metal trays of a vacuum shelf drier, the tray load being about 0.5 lb. per sq. ft. The atmosphere in the drying chamber was reduced to a pressure of 3 mm. of Hg, that is, to a very high vacuum. The shelf temperature was raised to 220°F. by steam circulating inside the shelves. Evaporation is so rapid that the juice becomes puffed by the rapidly evolved bubbles of escaping moisture vapor. Drying to 3 per cent moisture content required about an hour.

During the latter stages of drying the temperature should be reduced since the authors recommend that during drying the product temperature should not exceed 150°F. because of damage to flavor and color at higher temperatures. During the initial period of drying the very rapid evaporation of moisture from the juice cools it below the danger point. The insoluble-solids fraction from the centrifuge is also vacuum-dried, but separately from the serum fraction. After drying, both fractions are ground, screened, and recombined in a room maintained at very low atmospheric humidity. The final product is readily reconstituted to a paste, or a purée, or a juice by the addition of water.

A modification of the drying procedure consists in first preparing a paste of 25 to 38 per cent total solids content, whipping air into the paste to give a fluffy product, spreading this on the tray of the vacuum-drying oven, and drying under high vacuum as outlined above. The air bubbles in the paste expand during drying, and thus a fluffy or puffed dried product of good reconstituting quality is obtained after grinding.

Spray drying of tomato juice in standard powdered-milk drying equipment is difficult because of the tendency of the dehydrated product to remain rather soft or sticky while it is still warm. If the dried particles are cooled by introduction of unheated air into the exit end of the spray drier, the stickiness problem is overcome to a considerable degree. Work is still in progress. Addition of a small amount of bisulfite to the paste or juice before drying improved its stability during adverse storage conditions of the finished product.

Hohl and Smith (1944), in experiments conducted in the author's laboratory, found that a satisfactory powder could be obtained by peeling tomatoes as for canning, slicing, traying on slat-bottom wooden trays, exposing to the fumes of burning sulfur in a closed cabinet for 30 min., dehydrating at 140 to 125°F., transferring to a vacuum drier, and drying to bone dryness at 120°F. and 28 in. vacuum, grinding in a ball mill in a very dry atmosphere, and screening to 60 mesh. The resulting powder readily reconstituted in water to a juice or to other desired solids content. If the sulfuring (SO_2) treatment was omitted, the product was inferior in color and flavor; also, it did not keep as well after packaging. Light rapidly caused bleaching of the color and loss of vitamin C in the dried product. Vacuum packing in metal containers is recommended.

Wong et al. (1956) found that the powdered product should be packaged under vacuum or in inert gas with an in-package desiccant in order to attain maximum stability, particularly at temperatures of 90 to 100°F., such as would occur during the summer in many grocery stores. Also, under such conditions the moisture content of the product should not be above 2.5 per cent.

Tomatoes for export to Europe, as well as for the domestic market, for

use by commercial food processors are dehydrated about as follows: The tomatoes, preferably of a "nonjuicy" variety, are washed as for canning and sorted. They are then cut in thick slices, trayed on slat-bottom trays, sulfured in the fumes of burning sulfur for about 1 hr., and dehydrated in an air-blast dehydrater to low moisture content. The dried product may be used in the flavoring of soups and other food products. The San Marzano (Italian-plum-type tomato) is a good variety for drying because of its nonjuicy texture, high solids content, and small size. Tomato powder of excellent quality has been made by continuous drying *in vacuo* as previously described for orange juice.

Peppers and Pimientos. Dried hot peppers are used in large quantities by the Mexican population of the southwestern United States and Mexico. A considerable quantity of sweet peppers (pimientos) is dried for the manufacture of paprika, a sweet powder for use on the table and in cooking. A great deal of the dried hot red peppers are ground for packing as cayenne pepper.

The bags or crates of well-ripened peppers are emptied on trays made of fine-mesh (about 1-in.) chicken netting attached to a frame of 1- by 3-in. material, the usual tray being about 2½ by 5 ft. The peppers are sorted to remove green and spoiled specimens. They were formerly dried in natural-draft gas-heated driers at 110 to 160°F., a drying time of 3 to 5 days being required. Modern air-blast tunnel dehydraters were not utilized. Some operators slice the peppers and pimientos before drying, thus greatly hastening drying and improving the color and flavor. Also, it is customary to dice a considerable proportion of the pimientos, then separate the seeds from the diced material by screening and washing under sprays. Slat-bottom wooden trays are used for drying sliced and diced pimientos (see the following paragraphs for details). The whole peppers are dried until brittle and until the seeds and pulpy portions are thoroughly dried.

Another commercial method of dehydrating is about as follows: The pimientos are first passed through a revolving reel spray washer; then size-graded by machine to remove very small and broken specimens; sorted on a slowly moving belt to remove green and other pimientos unfit for drying; cut in half by machine and screened to remove and recover most of the seeds; cored; washed, resulting in separation of most of the remaining seeds; diced by machine; sulfited by sprays of dilute sulfite solution to give about 1,000 p.p.m. of SO_2 in the dried product; spread on slat-bottom trays; dried in an air-blast tunnel dehydrater at 120 to 165°F. to low moisture content; and drying is finished in bins at about 120°F. to less than 4.5 per cent moisture content.

The dried product is used in flavoring and improving the appearance of various food products, including canned. Some diced pimientos are par-

tially dried, then mixed with sufficient salt for preservation, and packed in barrels for use in various processed food products.

Grinding of sweet peppers for paprika and of hot peppers for cayenne pepper is done in centrally located mills. The peppers must be dried to a very low moisture content and milled very shortly after drying, as they become tough with absorption of moisture.

Sweet Corn. Corn has been dried in the sun or in ovens by housewives for many years, but its commercial-scale drying is of recent development. Properly dehydrated corn when soaked and cooked compares favorably with canned corn in quality. Only young tender ears of the best table varieties, such as the Golden Bantam or Country Gentleman or the modern hybrid varieties used for canning, should be used for drying.

The ears are husked as for canning and blanched in steam or boiling water 5 to 10 min. to cook the kernels, inactivate enzymes, and coagulate ("set") the juice ("milk"). They are silked and cut from the cob as for canning, spread on screen trays, and dehydrated to low moisture content. The product should be packed at once in insectproof containers since it is subject to attack by the Mediterranean meal moth and other insects. A finishing temperature of 150°F. can be used.

String Beans. Dehydration intensifies any toughness the fresh beans may have, making it necessary that only very tender beans be dehydrated. The Blue Lake, a pole variety used for canning and for freezing, is excellent for dehydration. However, any canning variety of tender texture and free of "strings" is suitable for dehydration. The beans are snipped as for canning. They may then be cut in short pieces and blanched for 3 to 6 min. in water at 185 to 190°F., depending on the size and maturity of the beans. Or the beans may be blanched whole and then cut lengthwise into French-cut strips; if blanched after cutting much soluble material is lost.

The cut beans should be spread in a thin layer since drying is slow and uneven in deep layers. They should be dried to less than 5 per cent moisture content. In our experiments at the University of California the drying ratio ranged from 7:1 to 10:1. Dehydration of green beans has been studied extensively by Litwiller and Pettit in the Department of Food Technology of Oregon State College, Corvallis, Oregon. Freezing of the blanched beans before dehydration was found to give a superior product.

Peas. Peas for dehydration should be even less mature than for canning, because of the tendency of starchy peas to become tough-skinned and mealy during dehydration. The so-called wrinkled varieties of high sugar content are to be preferred to varieties that are inclined to be starchy and low in sugar content.

The vines may be harvested and vined as for canning, as described in Chapter 10. They may be blanched as for canning, or they may be blanched

in live steam. They are spread on screen trays in a layer about ¾ in. deep. The finishing temperature should not exceed 145°F. since high finishing temperatures cause browning and loss of flavor. The centers of the peas dry slowly; hence they should be dried until entirely crisp, which is usually to below 5 per cent moisture content.

Spinach. Spinach requires very thorough trimming, sorting, and washing before dehydration. Blanching is done on the trays in live steam for 3 to 5 min. The leaves may be spread in a fairly deep layer on the trays before blanching, provided air flow between the trays is not seriously impeded.

The leaves dry very rapidly, and a relatively high temperature (165°F.) can be used. The stems, because of their greater thickness, dry more slowly than the leaves. The spinach should be dried to less than 5 per cent moisture and packed at once in packages that resist penetration of moisture. Spinach may be ground to a powder or pressed into briquettes if desired. The drying ratio is approximately 12 to 15:1.

Cabbage. During the Second World War all the belligerents dehydrated cabbage for use by their armed forces. In the United States it was one of the "big five," the others being potatoes, sweet potatoes, carrots, and onions.

The Savoy, a green-leaved variety, was considered best for dehydration in England and in tests at the University of California gave the product of highest quality. However, it is a shy bearer and is not grown extensively for commercial use. The Flat Dutch, a heavy-yielding white variety, was the least satisfactory of the commercially grown varieties in California, as it is very sensitive to heat during drying, giving a large percentage of discolored pieces. The Copenhagen Market, Golden Acre, Danish Ball Head, and Winningstadt are satisfactory and were dried commercially for Army and Navy use.

The cabbage is cut and loaded by hand in the field into trucks and hauled in bulk to the plant, where it is emptied into open bins. It is carried by conveyer belt to a crew who core each head by holding it against a revolving coring knife or other coring device and remove the outer leaves.

The cored and trimmed heads then are shredded in a kraut slicer into strips about ¼ in. wide. The strips fall directly to the 3- by 6-ft. trays, where they are spread by hand. The trays then travel through a long steam blancher, where they are subjected to live steam for about 4 to 5 min. Blanching should be sufficient to destroy the catalase enzyme but not all the peroxidase, since overblanching gives a product of poor color and texture. About halfway through the blancher, dilute sulfite-bisulfite solution is sprayed on the cabbage. Mackinney found this method of sulfiting much superior to sulfiting before or after blanching. If it is applied after blanching, the trays remain wet, and the dripping from one tray to the next will soil the cabbage. When it is applied during blanching, the trays emerge dry

and free of drip. In batch blanching in a steam cabinet it is also better to add the sulfite during than after blanching. The final sulfur dioxide content of the dried cabbage should be 1,000 to 2,000 p.p.m. In the author's experiments a 0.5 per cent solution of the mixed sulfite-bisulfite gave this range of sulfur dioxide in the dried product. However, the proper concentration must be determined by trial for any given set of conditions.

The tray load is about 1 lb. per sq. ft. The finishing temperature should not exceed 145°F. for sulfited cabbage and 140°F. for unsulfited. It should be dried to less than 4 per cent moisture. Drying is usually completed in bins at 115 to 120°F.

The cabbage should be carefully sorted after drying by inspection on a slowly moving belt. If it is to be held for several months in warehouse or on growers' shelves, it should be packed in gastight containers in inert gas such as carbon dioxide. It does not keep so well or so long as potatoes or carrots.

Dehydrated cabbage was used by Army and Navy cooks to prepare cole slaw, for which purpose it was reported very satisfactory. It was also satisfactory when cooked with corned beef or other cured meat.

Cauliflower and Sprouts. Brussels sprouts and cauliflower give fairly satisfactory dehydrated products. They are prepared as for cooking for the table; the cauliflower heads are also broken or cut in smaller pieces. They are blanched in steam 4 to 5 min. The temperature of drying should not exceed 140°F. because of their tendency to darken. Sulfiting as for cabbage is desirable.

Okra. Small pods may be dried whole, and large pods should be cut lengthwise in halves or quarters, or crosswise in circular pieces. Blanching in steam from 2 to 5 min. is advisable, followed by rinsing in cold water to remove the gelatinous coating formed in blanching. The finishing temperature should not exceed 140°F., and the drying ratio is approximately 10:1.

Celery. Both the leaves and stalks of this vegetable may be dried and used for the flavoring of soups, stews, etc., or for the preparation of powdered celery or celery salt. Only tender stalks relatively free from "strings" should be used. The stalks are trimmed, washed, and sliced. Blanching renders the product more tender, 2 to 3 min. in steam being sufficient. Celery leaves may be placed on trays separate from the sliced stalks; they require no blanching. The drying temperature should not exceed 140°F.

Rhubarb. Rhubarb is grown quite extensively in many states, especially in proximity to large cities. In the early spring, before fresh fruits and summer vegetables are available, rhubarb brings very profitable returns in local markets. However, the demand and, consequently, the price soon decrease, and it often happens that much of the later rhubarb is never marketed. For dehydration the stalks are trimmed, washed, and cut

into short lengths, which are blanched in steam 3 to 4 min. and spread and dried on trays at not above 160°F. The drying ratio is 13 to 15:1.

Garlic. Most plants engaged in the dehydration of onions also produce dehydrated garlic in flake, granular, and powdered forms. Garlic is of considerably lower moisture content than onions on arrival at the plant. It grows in the form of a clump of individual cloves loosely held together by a paperlike outer husk and rootlets. The first operation usually consists in drying the garlic a short time in an unheated air current so that the cloves can be easily separated. They are then passed between large rubber rolls set at such distance that the cloves are not crushed, but also sufficiently close together so that the clumps are broken up into individual cloves.

The pieces of paper husk are separated from the cloves by air-blast and screen-type cleaner, and the cloves classified by air flotation into several sizes. They are then transferred in water by pump to a baffle-type washer separator in which small pieces of stones and other heavy foreign material are separated from the cloves. In a second flotation separator pieces of skin and other light debris are floated away. The cloves are separated from the water by a dewatering screen. They are critically inspected and sorted on a belt. They are next sliced by special revolving, very sharp knives and spread automatically on trays, or on a perforated stainless-steel belt if a continuous dehydrater is used (see section on onion dehydration). Two-stage drying is used in tray-and-tunnel dehydration.

The sliced garlic is dried to about 8 per cent moisture, and drying is then completed in bins at 110 to 120°F. to less than 6.5 per cent moisture. The dried slices are carefully inspected and sorted in order to remove pieces of dark color; or they may be sorted by electric-eye sorter by equipment similar to that used for the sorting of dry beans for color. Production of powder and of free-flowing coarser powder is conducted in about the same manner as previously outlined for onions. Most of the dried product is sold in these forms. It has many uses in restaurants, hotels, and in other eating establishments and in the home. Also it is used in the flavoring of tomato products, canned soups, meat products such as sausage, hamburger, and salami, as well as in certain salad dressings.

Horse-radish. This vegetable retains its pungency when dehydrated. The radish is washed, trimmed, grated, and dried at a moderate temperature, 140 to 150°F. It can be refreshed in water plus distilled vinegar and used in the same manner as the fresh product.

Soup Mixtures. Soup mixtures were used extensively by armies in the field during the First World War and are still in demand for use on camping trips and to some extent for household use.

The pieces should be cut very thin or in small cubes or shreds so that they will cook quickly, and all except the onions should be thoroughly blanched before drying.

Various mixtures have been made. One recommended by Caldwell is potatoes 20 parts, turnips 20 parts, peas 20 parts, onions 6 parts, and carrots and beans 17 parts each. Flaked, cooked, dry white beans are used by one company to give a thicker consistency to the soup, and they make a valuable addition nutritionally because of their high protein content. Most soup mixtures contain celery in addition to the ingredients recommended by Caldwell, and tomato powder or shreds and pimiento are an improvement. Turnips tend to become brown on storage; if the soup mixture is not to be used promptly, they may be eliminated.

In preparing soup mixtures it must be borne in mind that since the mixture must subsequently be soaked and cooked as a unit, only such vegetables as absorb water and become cooked at approximately the same rate should be mixed. Peas and beans absorb water more slowly than the other vegetables named above unless they are cooked until almost ready for serving before they are dehydrated. Some European producers grind the dehydrated vegetable mixture and compress it into pellets or cylinders in order to conserve space and to give a product that cooks quickly.

Dried soup powders have also been produced commercially, particularly in European countries. Fidler et al. (1945) have described the manufacture of such products in England and in their pilot-scale experiments. The powders may or may not include meat or meat stock. One satisfactory formula was as follows: lean meat 320 parts, fat 55 parts, potatoes 650 parts, carrots 350, cabbage 192, oatmeal 43, yeast extract 13, salt 17, and pepper ½ part, all ingredients being in parts by weight. The meat is cut in pieces of medium size and roasted in order to intensify the flavor. The vegetables are sliced or diced. The meat and vegetables are cooked in a minimum of water to give a thick soup. The mixture is pulped in a tomato "cyclone" to give a purée. The purée is dried to less than 8 per cent moisture on a steam-heated drum drier. The flaky dried product can then be ground and sieved to obtain a soup powder. The final fat content should not exceed 8 per cent. The finished product should be packed in vacuum or in inert gas and when so packed is reported to keep well for at least a year at ordinary room temperature. The meat may be omitted if desired.

Single ingredients such as onions or dry peas or dry beans may be utilized as a basis for dry soup, onions usually in the dried-flake form and peas or beans in powdered form. For example, in experiments conducted in the Food Technology Laboratory at the University of California in 1955, the preferred procedure in making a powdered soup from Lima beans was as follows: The dry beans were cooked until well done in about 3½ parts of water by weight to one of beans; they were then sieved, dried to very low moisture content on a smooth metal surface heated by steam jacket to about 200°F., ground in a small mill, and screened to about 70 mesh. To this powder was added 40 grams of salt, dry thyme 3 grams,

dry celery flakes 3 grams, garlic, powdered, 5 grams, monosodium glutamate 5 grams, and parsley, dried, 3 grams to each 500 grams of the powdered beans. To prepare soup from this base add 10 parts by weight of water or milk and heat to the simmering point for a few minutes. The soup reconstitutes quickly.

REFERENCES

ADAM, W. B., HORNER, G., and STANWORTH, J.: Changes occurring during the blanching of vegetables, *J. Soc. Chem. Ind. (London)*, **61**, 96–99, 1942. See also Annual Report, Canning Research Station, Campden, England, 1941.

American Society of Heating and Ventilating Engineers: "Heating, Ventilating and Air Conditioning Guide," 1947.

ARTHUR, J. C., and McLEMORE, T. A.: Sweet potato dehydration: Effect of processing conditions and variety on properties of dehydrated products, *Agr. and Food Chem.*, **3**(9), 782–788, September, 1955.

BALOG, E. G., and CRUESS, W. V.: A note on dehydrated compressed vegetables, *Fruit Products J.*, **26**(2), 38, 54, October, 1946.

British Ministry of Food: "Handbook for Operators of Vegetable Dehydration Plants," London, May, 1944. See also special reports on same subject by same agency.

CALDWELL, J. S.: Varietal suitability in the dehydration of vegetables, *Food Packer*, August, September, and October, 1945.

Continental Can Company, Research Staff: "The storage characteristics and packaging requirements of some dehydrated fruits and vegetables: Special report," Chicago, Aug. 10, 1943.

CRUESS, W. V., FRIAR, H. F., and BALOG, E. G.: Notes on cabbage dehydration, *Fruit Products J.*, **23**(4), 113–115, 1943.

———, ———, and LEW, MARION: Potato dehydration, *Western Canner and Packer*, June and July, 1944.

——— and JOSLYN, M. A.: Significance of enzyme reaction in the dehydration of vegetables, *Proc. Inst. Food Technologists*, 1941, pp. 23–30.

——— and LOW, D.: Dry limas offer new product possibilities, *Western Canner and Packer*, **48**(2), 6, 1956.

——— and MACKINNEY, G.: The dehydration of vegetables, *Univ. Calif. Agr. Expt. Sta., Bull.* 680, September, 1943.

DAVIS, M. B., EIDT, C. C., and STRACHAN, C.: Factors affecting the quality of dehydrated vegetables, *Proc. Inst. Food Technologists*, 1942, pp. 90–99. See also Dehydration of vegetables, by same authors, in "Foods in Canada," Consolidated Press Ltd., Toronto, 1943.

Dehydration of carrots in a California plant, *Western Canner and Packer*, **36**(12), 53–58, November, 1944.

FIDLER, J. G., GANE R., DAVIS R., MAPSON, L. W., PINDER, J. L., and BISHOP, E. A.: Dried soup powders, *Food Manuf.*, **20**, 277–281, 1945.

FRIAR, H. F., and VAN HOLTEN, PHYLLIS: Effect of sulfiting on maximum drying temperatures of vegetables, *Fruit Products J.*, **24**(11), 337–339, July, 1945.

Good tomato powder made experimentally, *Food Eng.*, **27**(1), 111, January, 1955. Describes continuous vacuum dehydration process and equipment.

HAVIGHORST, C. R.: Continuous unit operations break bottleneck, *Food Eng.*, **27**(5), 63–66, 212, May, 1955. Onions.

Hohl, L. A., and Haas, V. A.: Experiments with powdered dehydrated vegetables, *Fruit Products J.*, **22**(10), 217, 305–308, June, 1943.

——— and Smith, M.: Comparison of vitamin content and palatability of frozen canned and dehydrated vegetable purées, *Fruit Products J.*, **24**(2), 54–56, 62, October, 1944.

Kaufman, V. F., Wong, F., Taylor, D. H., and Talburt, W. F.: Problems in the production of tomato juice powder, *Food Technol.*, **9**(3), 120–124, March, 1955.

Litwiller, E. M., and Pettit, L. A.: Dehydrated Blue Lake green beans, *Food Technol.*, **11**(4), 229–232, April, 1957.

Logan, P.: Dehydrated foods, *Quartermaster Rev.*, **22**(1), 31–34, 131, 1942.

Mackinney, G., and Fratzke, W. E.: Carotenoids of stored dehydrated carrots, *Anal. Chem.*, **19**, 614–616, August, 1947.

Makower, B., and Dehority, G. J.: Equilibrium moisture content of dehydrated vegetables, *Ind. Eng. Chem.*, *Ind.* Ed., **35**, 193–197, 1943.

Mrak, E. M., and Cruess, W. V.: Dehydration of vegetables, *U.S. Army, Q.M. Corps, Subsistence Div., Spec. Subsistence Bull.*, 1940.

Neel, G. H., Smith, G. S., Cole, M. W., Olson, R. L., Harrington, W. O., and Mullins, W. R.: Drying problems in the add-back process of production of potato granules, *Food Technol.*, **8**(5), 230–234, May, 1954.

Olson, R. L., and Harrington, W. O.: Dehydrated mashed potatoes: a review, AIC-297, *U.S. Dept. Agr., Western Regional Research Lab. Rept.*, January, 1951. Mimeographed. See also *Am. Potato J.*, **32**(3), 106–111, March, 1955.

——— and ———: Potato granules: development and technology of manufacture, pp. 231–256 in Mrak and Stewart (eds.), "Advances in Food Technology," Academic Press, Inc., New York, 1955.

Pitman, A. L., Rabak, W., and Yee, H. F.: Packaging of dehydrated vegetables, *Food Inds.*, **15**(1), 49–52, 104, 1943.

Proctor, B. E.: Report on the compression of dehydrated foods, *Mass. Inst. Technol. Dept. Food Technol., Rept.*, 1942. Mimeographed.

Reeve, R. M.: Facts revealed about vegetable dehydration by the microscope, *Food Inds.*, **14**(12), 51–55, 107, 1942.

Steam peeling of potatoes, *Western Canner and Packer*, **37**(3), 59–61, March, 1945.

Strashun, S. I., and Talburt, W. F.: WRRL develops techniques for making puffed powder from juice, *Food Eng.*, **25**(3), 59, March, 1953.

Sugihara, J., and Cruess, W. V.: Effect of blanching on the dehydration rates of vegetables, *Fruit Products J.*, **21**(5), 139–141, 1942.

——— and ———: Rapidly refreshing dehydrated vegetables, *Fruit Products J.*, **21**(10), 239–241, 1942.

U.S. Army Quartermaster Corps, Subsistence Research Laboratory: "Army Dehydrated Food Conference," Chicago, 1945.

U.S. Army Service and Supply, Council of Scientific and Industrial Research and Procurement Division: "Dehydration of Vegetables," issued by the Commonwealth of Australia, June, 1945. Mimeographed Report.

Vegetable and fruit dehydration manual, *U.S. Dept. Agr. Misc. Pub.* 540, 1944. See also Misc. Pub. 524, 1943, on the same subject.

von Loesecke, H. W.: "Drying and dehydration of foods," Reinhold Publishing Corporation, New York, 1943.

Wiegand, E. H., Madsen, H. S., and Price, F. E.: Commercial dehydration of fruits and vegetables, *Ore. Agr. Expt. Sta. Bull.* 417, 1943.

Wong, F. F., Dietrich, W. C., Harris, J. G., and Lindquist, F. E.: Effect of temperature and moisture on storage stability of vacuum-dried tomato juice powder, *Food Technol.*, **10**(2), 96–100, February, 1956.

CHAPTER 20

PACKING OF DRIED FRUITS AND VEGETABLES

The packing of sun-dried fruits is an industry separate and distinct from that of drying, although dehydrated fruits are sometimes packed in the same plants in which they are dried. Dehydrated vegetables are generally packed in the same building in which they are dried.

Importance of Dried-fruit Packing Industry. Table 34 shows the growth of the dried-fruit industry in California.

Approximately 15,000 tons per year of dried figs are packed in Smyrna. Greece, Australia, Asia Minor, and Spain pack and export large quantities of raisins, and Egypt, northern Africa, and Asia Minor produce most of the world's supply of dates. These fruits are in part packed ready for use, but much of the crop is shipped in bulk to America and Europe and is there processed and packed in cartons or boxes.

Oregon once produced approximately 25,000 tons of dried prunes per year, while New York and the Pacific Northwest are large producers of dried apples. Prunes in Oregon are now used chiefly for fresh shipment, canning, and freezing.

DRIED-FRUIT INSECTS

Insects cause in the aggregate enormous damage to dried fruits and vegetables and heavy financial losses to growers, packers, distributors, and consumers. Many of the operations of packing dried fruits and vegetables have for their purpose the destruction of insects and insect eggs and the exclusion of insects from the packed products. Figure 96 shows the more important forms.

General Types of Infestation. Three groups of insects are of importance in causing damage to dried fruits and vegetables. The most important group is that of the moths, including the Indian-meal moth (*Plodia interpunctella* Hubn.), the fig moth (*Ephestia cautella* Walk.), and the raisin moth (*Ephestia figulilella* Gregson).

Beetles are second in importance, of which the most common in dried fruits are the dried-fruit beetle (*Carpophilus hemipterus* L.), the saw-toothed grain beetle (*Silvanus surinamensis* L.), the foreign grain beetle

(*Cathartus advena* Waltl.), and a fungous beetle (*Henoticus serratus* Gyll.).

The third group of insects includes two sugar mites (*Tyroglyphus siro* Gerv. and *T. longior* Gerv.). These mites are of very small size, scarcely distinguishable by the unaided eye.

Indian-meal Moth (*Plodia interpunctella* Hubn.). Essig comments as follows on this insect:

> This insect is widely distributed and occurs not only in dried fruits but also in all cereal products, dry grains, seeds, nuts and many other foods. The larvae are yellowish-white and average about 1 inch in length. They are profuse web spinners and their webs, covering the fruit and containers, are more injurious to the appearance of the dried products than any other form of damage caused by this insect.
>
> The fully grown larvae enclose themselves in small white cocoons about ½ inch long. The chrysalids are brown.
>
> The moths average from ½ to ¾ of an inch in length. They are readily distinguished from other moths by the distinctive two-colored pattern of silvery-gray and bronze, the anterior portion of the wings being silvery and the posterior half bronze or copper colored.
>
> The very minute eggs are laid on or as near the dried products as possible, generally at night. The newly hatched larvae are very small and very active. They have a remarkable ability for locating dried fruit and will enter packages through very small cracks or other openings.

The remarkable reproductive power of this insect accounts for the sudden appearance in packing houses of enormous numbers of the larvae.

The moth is often found in dried fruit or refuse held over from the previous season. As a rule, public warehouses are infested with this insect and susceptible foods stored in such places invariably become infested. The appearance of this insect at various stages is shown in Figure 96.

Fig Moth (*Ephestia cautella* Walk.) is very similar in appearance and habits to the Indian-meal moth. The raisin moth, *Ephestia figulilella* Greg., resembles the other two moths in general appearance. It differs from them, however, in that it infests the fruit on the trays in the field, whereas the meal moth and fig moth are primarily indoor insects and breed in the warehouse.

Dried-fruit Beetle (*Carpophilus hemipterus* Linn.). According to Essig:

> This is the most injurious of the beetles that infest dried foods. The larvae are small and whitish-yellow and are distinguished from the caterpillars of the dried fruit moths by the fact that they possess only three pairs of true legs, whereas the caterpillars possess three pairs of true legs and three pairs of fleshy prolegs.
>
> The adults are short and robust, scarcely ¼ of an inch long. They are black in color, with reddish- or cinnamon-brown posterior portions. The larvae reduce the fruit to a fine powder or "frass," which is the excrement.

This insect ordinarily infests the fruit (particularly figs) while it is still in the field or dry yard. It is carried to the warehouses and packing houses in the fruit, where it thoroughly infests the premises. It is very active in laying eggs on figs during cooling of the fruit after processing [see Figure 96].

The insect has marked ability to locate dried fruit and, like the Indian meal moth, reproduces with astonishing rapidity.

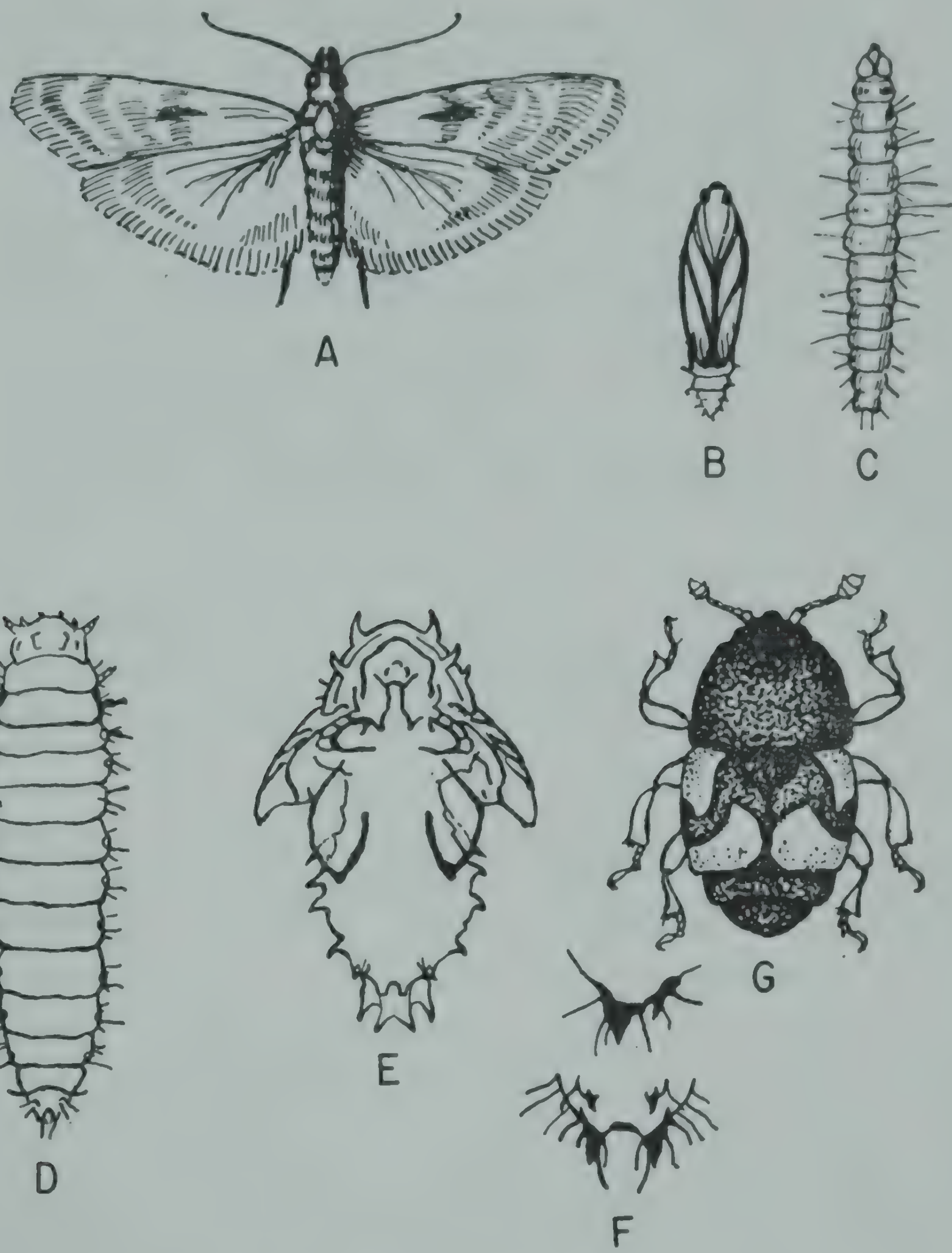


FIG. 96. Common dried-fruit insects. *A*, adult of Mediterranean meal moth; *B*, chrysalis; *C*, larva; *D*, larva of dried-fruit beetle; *E*, pupa; *F*, posterior appendage; *G*, adult beetle. (*A, B, and C after Chittenden; D, E, F, and G after Essig.*)

Saw-toothed Grain Beetle (*Silvanus surinamensis* Linn.). According to Essig:

Although of somewhat less importance than the dried fruit beetle, the saw-toothed grain beetle is, nevertheless, capable of causing extensive damage to dried fruits and vegetables. The larvae are small, about ¼ of an inch long and of whitish color. The adults are brown or blackish beetles ¼ of an inch long, slender and with saw-like teeth along the sides of the prothorax (neck). These teeth can be seen without a hand lens. They are particularly destructive to figs, not only destroying the inside of the figs, but also boring minute holes through the skins.

Clean Premises. The packing house should be kept clean, and it is good practice to clean the plant thoroughly at the start of the packing season. Fruit held over from the previous season or refuse fruit must be closely inspected and, if found infested, must be destroyed or fumigated or otherwise treated to eliminate the insects. It is good practice, where the walls are tight enough, to fumigate the plant throughout at the start of the season. Graders, conveyers, etc., must be thoroughly cleansed of webs, pupae, dried fruit, etc. Growers should not allow waste fruit, fruit pits, and fruit refuse to accumulate, because such material is a prolific source of infestation.

The dried-fruit beetle breeds profusely in piles of grape pomace from wineries. If the fresh pomace is spread thinly in the vineyard or orchard so that it will dry quickly, there is little danger of infestation from this source.

Figs left under the trees in the orchard provide excellent breeding places for the dried-fruit beetle.

The raisin moth is the principal cause of infestation of drying or dried fruit on the trays or of the fruit stored temporarily in the open in lug boxes or sweatboxes. Mulberries, which ripen and drop from the trees in considerable abundance in the San Joaquin Valley, serve as a breeding ground for this and other insects. Since this fruit ripens before figs and grapes, it serves as an important intermediate source of infestation. The eggs are laid at night and are killed when exposed to the direct rays of the sun. After the trays have been stacked, however, the fruit is protected from the sun, and eggs deposited at that stage of drying or those deposited in boxes of the dried fruit survive and hatch a good crop of larvae. It has been found by Simmons, Donohoe, and Barnes of the U.S.D.A., Bureau of Entomology, Fresno, California, and Fisher of the California Dried Fruit Association that covering the stacked trays and boxed dried fruit with shade cloth, such as that used for tobacco, very greatly reduces the crop of larvae by excluding the egg-laying moths.

Figs should not be allowed to lie on the ground after they have fallen from the trees, because they soon become infested with dried-fruit beetles that enter the fruit through the eye in the blossom end.

Fumigation. Fumigation, thoroughly applied, kills the insects in all stages of development, including the eggs, and does not injure the flavor, color, or texture of the fruit. It requires experience and great care. Carbon bisulfide and hydrocyanic acid gas were formerly the two fumigants generally used. The former is very inflammable, and the later deadly poisonous. They are being replaced with less dangerous fumigants. A satisfactory fumigant should be penetrating, nonexplosive, and inexpensive; it should not react with moisture or leave a poisonous residue.

Carbon Bisulfide. Carbon bisulfide is no longer used in California dried-fruit packing plants because of its extreme inflammability and explosiveness.

Hydrocyanic Acid Gas. In the past this gas has usually been obtained by the pot-generating method, but the liquefied gas in cylinders is more convenient. This fumigant should be handled only by experienced persons because of its intensely poisonous nature. There is some evidence to indicate that the fruit may retain a considerable proportion of the hydrocyanic acid gas, another reason for advising against its use. It has been replaced in California by other fumigants, notably methyl bromide, which is recommended for dried fruits.

Vacuum Fumigation. Considerable experimentation has been done in recent years by Federal and state authorities with a vacuum fumigator constructed of steel boiler plate and used as a fumigating chamber from which the air is drawn and vacuum conditions are created. Into this space the fumigants are drawn and come in intimate contact with the materials placed inside for treatment, which generally lasts for 1 hr.

The advantages of such an apparatus include thorough penetration of the vapors into the densest food materials, rapidity of action, and safety of operation. It can be applied to packed as well as to bulk goods.

It is used for walnuts and almonds rather than for dried fruits.

Methyl Bromide. This fumigant has come into general use recently owing to its effectiveness and its relatively nonexplosive character. It is extremely toxic to insects. Unfortunately, it is also toxic to man. It is supplied in liquefied form in cylinders and may be piped to the fumigation chamber, thus reducing the danger to workmen. Small cylinders of the liquefied gas may be opened in the fumigation chamber safely if a mask is worn or if the operator avoids breathing the fumes. It is liberated near the top of the chamber, as the gas is heavier than air.

The usual dosage is 1 lb. per 1,000 cu. ft. One large packer stores 5,000 tons of dry fruit, which is fumigated with methyl bromide frequently in order to prevent infestation.

Methyl bromide appears to leave no poisonous residue in the treated fruit. In addition to its efficiency in exterminating insects, it is also extremely effective in destroying rodents in dried-fruit warehouses.

Ethylene Dichloride and Carbon Tetrachloride Mixture. This mixture is noninflammable and nonexplosive. It leaves no poisonous residue in the treated fruit. It has an anesthetic effect on man but is not particularly irritating to the eyes or respiratory organs. The dosage is 15 to 20 lb. per 1,000 cu. ft. of fruit and space. It is much less toxic to insects than methyl bromide, but is fairly effective if the fumigating chamber is reasonably gastight. Artificial heating or use of burlap sacks as wicking is usually necessary for effective evaporation to form a vapor, as these substances are liquids at ordinary temperatures.

Ethylene Oxide and Ethylene Dichloride Mixture. A mixture of about 25 per cent of liquid ethylene oxide and 75 per cent liquid ethylene dichloride

is often used as a so-called "line fumigant" for boxed dried fruit. About 10 cc. of the mixture is added to each 25-lb. box of the fruit just before sealing. This fumigant is only slightly toxic to man. Prolonged breathing of the fumes may anesthetize or may cause vomiting. It is not so good a fumigant as methyl bromide for use in bulk fumigation.

Ethyl Formate. This volatile liquid is added by some packers to the boxed dried fruit at the rate of about 5 cc. per 25-lb. box.

Chloropicrin. This is the familiar tear gas of war days and is known also by the names "nitrochloroform" and "nitrotrichloromethane." It is poured on folded burlap bags on trays in the fumigating chamber, or the workman may spray it from a small pressure cylinder if he wears a protective mask.

The gas is extremely irritating to the eyes and mucous membrane; hence it declares its presence in no uncertain manner. Consequently serious injury from its use is uncommon. It is nonexplosive. The dosage is 1 lb. per 1,000 cu. ft.

Dried fruits should be delivered by the grower to the packer as soon as possible after removal from the trays, as the packer has facilities for fumigating the fruit to kill insects and eggs. If it is necessary to store dried fruit for several months on the farm, some provision for effective fumigation should be made. Chloropicrin is satisfactory.

Sulfur Dioxide. Apricots during the packing process are wet with water and are treated 4 to 12 hr. in the fumes of burning sulfur. Parker found that this treatment destroyed all insect life on the fruit fumigated in bulk. It may be used for all fruits that are sold in the sulfured condition, such as apples, sulfur-bleached raisins, sulfured apricots, peaches, pears, and sulfured Adriatic-variety figs. It is inexpensive, simple, and easily applied.

Fumigation Sterilization. Recently Mrak and Phaff of the University of California have found that yeasts and molds in packaged dried fruits can be killed by propylene oxide added before sealing of the package. The new procedure is now in commercial use for dried fruits of high moisture content.

Fumigation of Figs. Figs are allowed to partially dry on the tree and drop to the ground naturally. Many become infested with fig beetles. Therefore, it is essential that this fruit be fumigated before placing on trays and again on removal from the dry-yard trays.

Fumigating Chambers. For fumigating figs, raisins, and other fruits on the farm, small, tight outdoor houses similar to sulfur houses may be constructed. Refrigerator- (icebox-) type doors should be used. If of wood, the construction should be tongue and groove of double thickness, with building paper between the walls or used as a lining. A simple, inexpensive fumigating hood, a rectangular box large enough to cover a stack of trays, may be built of rubberoid roofing paper over a light wooden frame. Indoor storage bins may also be enclosed, but for them only nonexplosive, noninflammable fumigants should be used.

The principal requirement is that the chamber be as nearly gastight as possible. Otherwise the fumes, gas, or vapor soon leak out of the chamber, and the insects and eggs are not killed.

The chamber should be provided with a vent to the outside atmosphere, which may be opened when fumigation is complete.

Dosage. The dosage is usually expressed in pounds of fumigant per 1,000 cu. ft. of fumigation chamber space. The "space" includes that occupied by the fruit as well as the unoccupied space. For a rectangular chamber the space is calculated very simply as follows: volume in cubic feet equals length × width × height in feet.

Use of Insecticides in the Soil. As outlined in the section on fig drying in Chapter 17, it has been found feasible to kill the adults, larvae, and eggs of beetles that infest figs and which spend much of their life span in the soil by spraying or dusting the soil with a powerful contact insecticide, such as dieldrin, followed by disking the insecticide into the soil.

Screening Out Insects. Many of the insect larvae in raisins may be screened out on vibrating screens of large enough mesh to pass the larvae and small enough to retain the raisins. However, this is rather a makeshift and not very commendable procedure. Infestation should be prevented in so far as possible.

Insect-damaged fruits can be detected readily by the methods devised by Howard of the U.S.D.A., by Fisher of the Dried Fruit Association, and by others (see section at end of this chapter).

Heat as an Insecticide. In the processing of prunes, "practically peeled" dried peaches, seeded raisins, and dried figs, the fruits are passed through boiling water or dilute solutions of salt or sodium bicarbonate. The fruits are thoroughly cleansed, and all insect life is killed by heat.

Several packing houses during the Second World War treated dehydrated vegetables by dry heat for several hours at 145 to 150°F., a treatment found convenient and very effective. The dry-heat process may be made continuous by use of superimposed screen conveyers placed in a chamber heated by steam coils, gas, and a current of heated air. Any good dehydrater can be used for the purpose. A temperature of 180°F. can be used for products not injured at this temperature, and the time of treatment shortened to a few minutes. However, if vegetables are dried to very low moisture content (5 per cent or less) and packed in hermetically sealed metal containers, there is little danger from insects.

Products sterilized by heat must be packed immediately to avoid reinfestation, unless stored in an insectproof room. The containers must also be sterilized, as they may contain insect eggs.

Insectproof Packing Rooms. Packing rooms should be of tight construction, so that they may be fumigated occasionally. Doors and windows must be screened to exclude insects. If these precautions are taken, much insect infestation in packed goods may be avoided.

Insectproof Packages. Tin cans, either friction-top or hermetically sealed, are proof against insects and are ideal containers for fruits and vegetables shipped to or through the tropics or to warm, humid districts, such as the southern United States. They have not been generally adopted because of their relatively high cost and because the public is accustomed to purchasing dried products in paper cartons or boxes and is slow to become accustomed to new styles of containers. However, they deserve greater popularity. They were very generally used by the Army during the Second World War.

Parker has found that the usual dried-fruit boxes and cartons are not proof against insects. He has developed a process of wrapping small cartons (1- to 10-lb. sizes) in waxed paper, as is done with cereal cartons, to exclude some insects effectively. Inner liners, as well as outside wrappers, of aluminum foil are very effective and are in use. Sealed packages also reduce the tendency of dried fruits to lose moisture and to become sugary on the surface, and they also prevent excessive absorption of moisture by dried vegetables. Fruit beetles and grain beetles often gnaw holes through such packages, thus gaining entrance. Some insects will penetrate metal foil in this manner. The work of Essig, Smith, and others showed that certain insects, such as the cadelle, bore holes through most nonmetallic packages "just for the fun of it" and thus admit other insects that destroy the dried food. They found that cartons coated with Dewey and Almey microcrystalline wax are very resistant even to borers. They are also moisture-repellent.

Fruit treated in boiling water or steam before packing should be allowed to dry on the surface before being placed in wrapped cartons; otherwise molding may occur.

Effect of Cold Storage on Insects. It has been found by De Ong of the University of California and Simmons of the U.S.D.A. that the development of insects is prevented if dried fruits are placed in ordinary commercial cold-storage warehouses at 36 to 40°F. The insects remain dormant but are not killed unless the storage is prolonged 3 to 4 months. This means of storage is used extensively during the summer months in large distributing centers, such as New York and Chicago.

Rodents. Rats and mice cause great damage in dried-fruit packing plants. For discussion of this subject and other phases of plant sanitation see Chapter 26.

PACKING DRIED APPLES

Dried apples are usually packed by those who dry them and in the same building in which the drier is located.

Grading. Five grades are generally recognized in the trade, as follows:

Extra Fancy. Rings of fairly uniform size; uniform white color; clean;

free from skins, cores, stems, bruised or rotten spots, wormholes, or screenings.

Fancy. Rings of fairly uniform size; uniform white or very light yellow color; clean; almost free from skins, cores, stems, bruised spots, wormholes, or screenings.

Extra Choice. Rings of fairly uniform size; white or light yellow color; not more than 25 per cent of pieces showing skins, cores, stems, bruised or rotten spots, or wormholes; nearly free from screenings.

Choice. Rings of white, yellow, or light brown color; not more than 50 per cent of pieces showing skins, cores, stems, bruised spots, or wormholes; may contain a noticeable amount of screenings.

Standard. Brown color; large percentage of pieces showing skins, cores, stems, or bruised spots; considerable screenings present.

According to Beattie and Gould, only three grades are recognized in some apple-drying districts. These grades are Fancy, Choice, and Prime. Fancy corresponds to Extra Fancy in the above list, Choice to Fancy, and Prime corresponds to Choice. The fruit not suitable for the Prime grade is cull or substandard and should be used only for by-products. The terms A, B, and C are also used as grade designations. The grades established by the U.S.D.A. are A, or Fancy, B, or Choice, and C, or Standard (see definitions at end of this chapter).

Curing and Processing. Dried apples are often stored in bins or heaps on the floor and are generally shoveled over several times during curing. It is customary in many plants to overdry the apples slightly and to return water in the pile by sprinkling and shoveling over. Unless the addition of water is carefully controlled by frequent analyses, there is danger of addition of so much water that the apples will spoil in the package or will exceed the government standard of 24 per cent for moisture content. Some plants now pack the dried apples directly after dehydration. This is much the more sanitary and satisfactory procedure. Whether from bins or direct from the drier, the apples are cleaned by passage over shaker screens to remove seeds and fines and are then carefully sorted on a slowly moving belt. They are moistened, if water has not been added previously. They are then spread deeply on trays and sulfured several hours to 2,000 p.p.m. or more sulfur dioxide content.

The moisture content can be determined fairly accurately by drying a 10-gram sample for exactly 4 hr. at 200 to 212°F. (92 to 100°C.) in a water-jacketed oven, although the official method consists in drying a 10-gram sample *in vacuo* at 29 in. mercury and 70°C. (158°F.) for exactly 12 hr. However, moisture is usually determined by the Dried Fruit Association electrical-conductivity instrument. Assays can be made accurately to within 0.1 to 0.2 per cent moisture in less than 3 min.

Packing. Dried apples are in suitable condition for packing when they

have passed through the curing period and the individual pieces have all become pliable and have acquired a uniform moisture content. This is determined by their appearance and texture.

Dried apples are usually marketed in 25- or 50-lb. boxes. For a fancy pack the side of the box intended for the top is packed first, as in the packing of fresh fruit in barrels, and the pieces for the first layer are therefore carefully selected perfect rings. They are faced very carefully with the rings overlapping each other in rows lengthwise of the box on a lining of paraffined paper.

After facing, the box is filled, the contents being firmly packed in with a press made for the purpose, and the box is weighed to ensure full measure. The cover (which then becomes the bottom) is nailed on.

Other Apple Packs. Some dried apples are coarsely ground and packed in cellophane bags for use in making applesauce.

The Vacu-Dry Company in California grinds dried apples coarsely, then dries them *in vacuo* to below 2 per cent moisture. They are packed in moistureproof containers under the name of "apple nuggets." They may be cooked quickly for sauce and keep well.

PACKING DRIED APRICOTS

The process of preparing dried apricots for packing is very simple; elaborate equipment is not necessary or generally used.

Receiving and Sweating. The apricots are delivered to the packing house in sacks or in lug boxes and are then stored in large bins or boxes to undergo equalization of moisture and to await final processing and packing.

In California the grower's fruit is often sampled as received, and he is paid according to the quality and size of the fruit. The fruit should not contain more than 15 to 16 per cent moisture on delivery.

Quality Grades. In the packing houses of the Prune and Apricot Growers' Association of California, five quality grades are made, as follows: Sunsweet quality, which is the best fruit only; Growers' Brand, sound fruit of good quality free from black or other off-quality specimens; Number One Slabs, equal to Growers' or Sunsweet quality in color and flavor, but flat and thin because of overripeness; Number Two Slabs, which may contain off-color specimens; and finally culls, including all unmerchantable fruit. Other packers have similar grades, but usually under other names.

Size Grading. Apricots are often size-graded before storage, because the fruit then moves freely on the screens and is not matted.

The grader consists of a long vibrating screen made up of sections with holes of different diameters. The grader is very similar in appearance to that used for peeled peaches and shown in Figure 16. The following size grades are made:

1. Extra Fancy, over 48/32 in. in diameter
2. Fancy, 48/32 in. in diameter
3. Extra Choice, 40/32 in. in diameter
4. Choice, 32/32 in. in diameter
5. Standard, below 32/32 in. in diameter

These size grades apply to both Sunsweet and Growers' Brand qualities of apricots.

The graded fruit falls into portable boxes or large wheelbarrows, in which it is transferred to the storage bins or to the processor.

Processing. The fruit passes first over a vibrating screen to remove leaves, stems, and other refuse and to break up lumps of matted fruit; then through a small tank of cold water to remove dust, to wet the fruit to facilitate absorption of sulfur fumes, and to render the pieces more pliable.

They then pass beneath sprays of water on a vibrating screen and pass over the end of the screen to 6- by 3-ft. wooden trays. The fruit is spread 2 to 3 in. deep on the trays, and the trays are stacked in staggered position on a car. In processing, 10 to 12 per cent moisture is absorbed.

Sulfuring. The trays of fruit are placed in sulfur houses and allowed to remain in the fumes of burning sulfur several hours or overnight for the purpose of destroying insect eggs and impregnating the fruit with enough sulfurous acid to prevent darkening of color and fermentation or molding in the final packages. For the United States market the SO_2 content is usually above 3,000 p.p.m. and for some export markets must not exceed 1,500 p.p.m.

Boxing and Pressing. Some of the fruit is packed in fiberboard or wooden boxes holding 25 and 50 lb., filled from an overhead bin and delivery spout. The filled boxes are weighed, and the fruit pressed into the containers by a plunger or by continuous mechanical pressing device. Cartons and plastic bags holding 1, 2, 3, and 5 lb. are also used.

Prices According to Grade. The price paid the grower or dry-yard operator varies according to size and quality of the halved, dried pieces. The following prices were paid several years ago by the Association and illustrate the price range, although present prices are considerably higher:

Sunsweet Quality	Cents	Growers' Brand Quality	Cents
Choice	24	Choice	22½
Extra Choice	26	Extra Choice	24½
Fancy	28	Fancy	26½
Extra Fancy	30	First Quality Standards	18
Fancy Moorparks	30	Slabs	20
Extra Fancy Moorparks	33		

PACKING DRIED FIGS

The basic principles and practices of fig packing are similar in the United States and Asia Minor, although in America laborsaving machinery is used to a greater extent and more attention is given to sanitation.

Sorting. Figs of the Calimyrna variety are sorted before processing in order to remove those that have soured by endosepsis or are otherwise unfit for packing. The sorters must be trained to recognize soured dried figs from their outward appearance. In at least one plant "mummies" (small, immature dry figs of light density) are separated from the good figs by a very powerful updraft air stream, a method devised by C. D. Fisher.

Grading. Figs are graded for size by graders similar to those used for apricots. The following sizes are recognized in California:

1. Black figs (Mission variety): Standard $^{26}/_{32}$ in. in diameter, Choice $^{30}/_{32}$, Extra Choice $^{34}/_{32}$, Fancy $^{38}/_{32}$, and Extra Fancy over $^{38}/_{32}$ in.
2. Calimyrna (white) variety: Standard $^{30}/_{32}$ in. in diameter, Choice $^{34}/_{32}$, Extra Choice $^{38}/_{32}$, Fancy $^{44}/_{32}$, and Extra Fancy over $^{44}/_{32}$ in.

See the section at the end of this chapter for U.S.D.A. grades.

Dipping. Before packing, figs are treated in boiling water or in dilute fig sirup or dilute corn-sugar solution. The figs are carried through the boiling liquid on a conveyer in perforated sheet-metal buckets, the usual time of immersion being 45 to 90 sec., depending upon the water content of the figs and the variety.

Dipping destroys insect life, softens the skins, renders the figs pliable, and incidentally increases their weight. Calimyrna figs may be heated in dilute fig sirup, drained, and then heated briefly in a retort under steam pressure. This treatment imparts a light brown color and glossy luster to the figs. Or they may be heated in water briefly and then retorted. Retorting must not be overdone or it will caramelize the figs and make them sticky.

Brick Pack. After dipping, some figs are allowed to stand overnight. The figs are then placed before women workers who slit one side of each fig from the stem to the eye with a sharp knife. The fig is rolled between the thumb and fingers and flattened out in such a manner that the cheeks are spread wide apart and the stem is concealed. Spoiled fruit, such as that containing smut, is discarded. The figs are spread to such width that they will fit snugly into small forms made of hardwood. When full, these forms are placed beneath a press that compacts the figs into bricks and are allowed to stand overnight. The figs are then removed from the forms and wrapped in waxed paper, and a lithographed label is attached around the brick lengthwise. Uncut Black Mission figs and Calimyrna figs are also packed in bricks and wrapped in cellophane.

The bricks are prepared from Extra Choice and Fancy fruit and are of 4-, 6-, 8-, 12-, and 16-oz. sizes. The best grades are packed in lithographed cartons or wrapped in cellophane.

High-moisture Packs. As a result of research and development work by E. M. Mrak and H. J. Phaff of the University of California, C. D. Fisher of the Coast Laboratories of Fresno, California, and commercial packers of figs, a large proportion of the dried-fig crop is packed at high-moisture content (approximately 30 per cent H_2O content) and sterilized in the package by a fumigant that kills not only insects but also yeasts and molds. In one plant the procedure is about as follows: The dried figs as received from the grower are size-graded and analyzed for moisture content. They are also examined critically in respect to quality and insect infestation. They are then stored in tight rooms under continuous fumigation with methyl bromide.

When needed for packing the figs are removed from storage and processed in hot water to increase the moisture content to about 30 per cent. They are allowed to stand overnight in boxes in order to permit moisture penetration and equalization. They are then carefully sorted to remove broken or otherwise unfit fruit and are packed by hand into lithographed plastic bags of 12-oz. net contents for the retail trade. The filled but open bags pass beneath an applicator that automatically adds to each bag a measured amount of special fumigant. The bags are automatically heat-sealed. The fumigant sterilizes the fruit and interior of the package. Within a few days after packing, the fumigant disappears and leaves no undesirable flavor or odor in the product. The automatic applicator was invented by C. D. Fisher.

The high-moisture figs have been given various names by the packers, such, for example, as "softenized." They are excellent for eating out of hand. A similar pack of dried prunes is on the market and is increasing rapidly in popularity.

Bulk Pack. Figs that are not satisfactory for bricks, carton, or fancy box packs are packed in 25- or 50-lb. boxes for the baking and biscuit trade or are used for fig meats, paste, and a confection base. Some of the best quality are water-blanched, sorted while hot, "pulled," i.e., manipulated with the hands until soft and pliable, and packed in 5- to 25-lb. boxes as a fancy pack.

Fig Paste. Much of the dried fig crop of California is converted into paste for use in fig "newtons" (fig cookies) and other bakery or cracker products and confectionery.

The dried figs, if very hard and dry, are steamed or heated a short time in water at about 140°F. to soften them. If the figs are too soft to grind, they are spread on trays and dehydrated to remove excess moisture.

They are sliced by machine and sorted on a broad belt to remove figs

showing black mold, souring, and insect infestation. Following sorting, they are washed thoroughly and spread on trays a day or two to dry and to permit sampling and microscopical examination of samples.

The figs are then ground to a paste in a two-stage grinder in which the fruit is forced through ⅜-in. holes in a grinder plate against revolving blades and then through ⅛-in. holes, also against a revolving knife.

The paste is bulk-packed for the confectionery and baking trades; very little enters the retail trade in its original condition. If packed at too low moisture content it is apt to "set up" to a solid condition.

At present fig paste is a very important outlet for California figs. It is much in demand in the baking and cracker industries.

Fancy Packs. Much of the large fruit is used for special packs. The figs immediately after dipping are carefully inspected for smut and insect damage. They are then pulled and formed into the desired shapes.

Circular boxes are often used as containers, the figs being packed in concentric rings. Usually the surface layer of such packs consists of black and white figs arranged in an attractive pattern.

Layer raisins, peeled dried peaches, nuts, and figs are employed in making up Christmas boxes holding about 10 lb. each. All cartons and bricks are sterilized by heat or by fumigant before shipping.

Packing Imported Figs. Considerable quantities of figs from Mediterranean countries are imported to the United States and packed in New York and other large cities.

Fig Souring and Smut. The white varieties of dried figs, Smyrna (Calimyrna) and Adriatic, sometimes contain a profuse growth of black mold spores. Infection occurs in the orchard, and most of the growth probably occurs before the fruit reaches the packing house. It is practically impossible to identify figs containing this mold unless the figs are cut or torn open. The Mission fig is not affected by the sooty mold, probably because its eye is sealed against entrance of the organism. Most white figs are cut open as described previously before packing, to permit removal of moldy figs. Many Calimyrna figs are infected with the organism of endosepsis by the fig wasp, which carries pollen into the fig to fertilize it. Infected figs undergo internal rotting and souring on the tree. On drying, the fermented figs usually are of lighter density than the sound ones and possess a disagreeable musty-sour odor. These figs are removed by sorters.

PACKING DRIED PEACHES

Sun-dried peaches are packed in two forms: unpeeled and "practically peeled." In California much of the dried peach crop is packed by the California Prune and Apricot Growers' Association, a cooperative organization with headquarters at San Jose.

Grading and Storing. The peaches are graded for size on mechanical graders, as described elsewhere for apricots, and the grower is paid according to the amounts of each size delivered. The size grades are as follows:

1. Extra Fancy, over $^{58}/_{32}$ in. in diameter
2. Fancy, $^{58}/_{32}$ in. in diameter
3. Extra Choice, $^{50}/_{32}$ in. in diameter
4. Choice, $^{42}/_{32}$ in. in diameter
5. Standard, $^{34}/_{32}$ in. in diameter

Dried peaches are divided into two general classes, viz., Muirs and Yellows, the latter term including several yellow-fleshed freestone varieties, principally the Lovell and Elberta. The Muir peach is preferred to other varieties on account of its color, flavor, and sweetness. The U.S.D.A. has established specifications for U.S. grades of dried peaches.

The graded peaches are stored in bins until they are to be packed. The moisture content at the time of binning should not exceed 16 per cent, in order that matting and crushing may not occur.

Fumigating. Fumigation of the dried fruit is desirable, if it is to be stored several months before packing.

Packing Unpeeled Peaches. Unpeeled peaches are processed and packed in the same manner as described elsewhere for apricots.

Dehydrated Clingstone Peaches. A large tonnage of clingstone peaches is produced in California for canning fresh, and a small quantity is dehydrated. The peaches are pitted, lye-peeled, sulfured, and dehydrated. The dehydrated fruit is moistened, resulfured, and packed as described for apricots.

"Practically Peeled" Peaches. This process was developed by the late W. H. Beekhius, formerly factory manager of the Peach and Fig Growers' Association and later field manager of the Dried Fruit Association.

The dried peaches are carried on a metal conveyer through a boiling sodium bicarbonate solution, approximately 20 per cent, which loosens the skins. They then pass through a screen cylinder in which revolve stiff-bristled spiral-shaped brushes. These brushes rub the peaches against the screen and thus remove the loosened peels; and sprays of water wash the peels and adhering soda solution through the screen to the waste drain. This process removes most of the peel from the ripe fruit, but unripe peaches do not peel satisfactorily.

The "practically peeled" fruit next passes by means of a conveyer through a tunnel drier heated by steam coils. This removes excess surface moisture, which would otherwise cause molding or fermentation in the packages or, by drying after a few weeks' storage, would cause the packages to contain a much lower net weight of fruit than was placed in them at the time of packing.

The peaches are spread on trays and sulfured, usually overnight. They

are packed in attractively lithographed cartons holding 1, 2, and 5 lb. each.

Other Packs. Some dried peaches are packed in transparent plastic bags such as pliofilm. Some are mixed with prunes, pears, and apricots as a mixed pack.

PACKING DRIED PEARS

Dried pears, because of the heavy sulfuring given them before drying and because they are removed from the trays while still pliable, usually require no processing in water or sulfuring before packing.

Grades. In a large dry yard and packing house in central California the pears are graded for size and quality by women who stand before a slowly moving belt. The grades made in this plant are Jumbo (largest and finest fruit), Extra Fancy, and Northern California pears. The three best grades are packed as Lake County pears. In another packing house the following grades are made: Extra Fancy, Fancy, Extra Choice, Choice, and Standard. Great care must be taken to remove fruit that shows insect damage, which is usually done by codling-moth larvae before picking or during ripening after picking.

Packing. The sorted fruit is packed principally in 10-, 25-, and 50-lb. boxes. Some are packed in small cartons or plastic bags, and others are packed with other dried fruits in a mixed pack. Overdried fruit is processed before packing, as described elsewhere for apricots.

PACKING DRIED PRUNES

The processing, grading, and packing of prunes is a specialized industry, separate and distinct from the growing and drying industry. While the varieties of prunes are different in the two regions, the methods followed in the commercial packing of prunes in the Pacific Northwest and in California are very similar.

Receiving and Door Test. The prunes are generally allowed to undergo sweating in bins or boxes at the dry yard or drier before delivery to the packing house.

In most packing houses each load of prunes as delivered is sampled carefully, its quality, moisture content, and the number per pound being determined. Moisture is measured on a ground sample, including the ground pits, by use of the Dried Fruit Association electrical-conductivity moisture tester devised by C. D. Fisher. This is known as the door test, on the basis of which packing houses pay the grower.

Grading. Each lot is size-graded, in most packing houses immediately after delivery, and the weights of prunes falling into the different-size grades are determined. A grader similar to that used for peaches for can-

ning, equipped with vibrating screens with circular openings, is used for grading. Immediately beneath each screen is a bin; thus prunes of 40 to 50 size fall into one bin, 30 to 40s, etc., into other bins. The graded prunes are transferred to large wheelbarrows or trucks for weighing and are transported to storage bins. The usual size grades and corresponding diameters of screen openings are given in Table 46.

TABLE 46. SIZE GRADES FOR DRIED PRUNES IN CALIFORNIA

No. of prunes per lb.	*Diameter of grader holes, in.*
20–30	42/32
30–40	40/32
40–50	38/32
50–60	36/32
60–70	33/32
70–80	33/32
80–90	30/32
90–100	28/32
100–110	26/32
110–120	24/32
120 and up	Below 24/32

SOURCE: After Cruess and Christie, "Laboratory Manual of Fruit and Vegetable Products."

Before entering the grader the prunes pass over a vibrating screen which removes loose dirt, leaves, stems, etc.

Processing. The fruit is sorted to remove slabs, splits, and other culls. The processing of dried prunes consists in immersing them in hot water for a period of 2 min. or more in a processor. This consists of a long metal tank filled with water heated to boiling or nearly to boiling by steam coils or open-steam jets and of a conveyor equipped with perforated sheet-metal buckets.

Another procedure consists of a short immersion in hot water, followed by steaming for several minutes. The steaming partially cooks the prunes and renders them quick-cooking.

Processing cleanses the fruit, destroys all insect life, and renders the prunes soft, pliable, and of glossy appearance. The fruit increases in weight about 6 to 8 per cent through absorption of water.

Packing and Cooling. Some of the prunes are packed directly from the processor without drying or cooling, 25- and 50-lb. fiberboard boxes lined with paper being the usual containers. The hot fruit is filled into the boxes by weight and pressed flush with the top of the box with a hand-lever or power press or with a continuous dried-fruit press.

The boxes retain a high temperature for several hours if packed closely together, resulting in caramelization of the sugars in the fruit and in severe injury to quality. The boxes are therefore stacked in staggered fashion so

that air currents may pass freely between them and cool them reasonably rapidly.

Cartons holding 1 and 2 lb. of prunes are now used rather extensively. They are of convenient size for the average family and usually ensure that the prunes reach the consumer in good condition. They are filled to weight and are wrapped by automatic machinery.

There is increasing use of pliofilm and other tough, transparent plastic bags for dried prunes. The processed prunes are cooled before packing, and a measured volume of a special fumigant such as ethylene oxide is added to each package before sealing.

Canning. Some prunes are packed scalding hot in cans and sealed under a high vacuum. When packed in this manner, they preserve their original glossy appearance and soft texture and do not undergo "sugaring." They are also packed hot into cans and exhausted in live steam for 15 min. before sealing. Unless they are vacuum-sealed or thoroughly exhausted before sealing, corrosion and perforation of the tin plate are very common and spoilage losses from these sources are very heavy. Prunes to be eaten out of hand as a confection should be blanched in boiling water until they contain about 32 to 33 per cent moisture. They are canned scalding hot in double-enameled Type L cans, exhausted 10 min., sealed, and processed 30 min. in boiling water. The resulting product is very attractive and tasty.

Prunes are also canned in dilute sirup, in ready-to-serve form. Briefly, size-graded dry prunes are blanched in boiling water 8 to 10 min.; they are canned in Type L cans, and a sirup of 20° Brix is added; the cans are exhausted in live steam for 15 min.; then sealed and processed in boiling water 30 to 60 min., depending on size of can.

Pitted Prunes. Small prunes, sizes smaller than 100 to the pound, are often used for the preparation of pitted prunes sold to the baking trade in 25-lb. boxes. Some prunes of larger sizes are also pitted. They are excellent for fruit cakes, plum puddings, and pies and can be used in bread as a substitute for raisins.

The prunes are first treated 6 to 7 min. in boiling water, or preferably a longer time in live steam, then spread on trays which are stacked and allowed to stand overnight to permit the prunes to soften, after which they are dried a short time to remove surface moisture so as to prevent sticking of the fruit to the pitting machine. They are pitted by a machine similar to that used for seeding raisins.

High-moisture Prunes. As outlined earlier in this chapter, a considerable quantity of prunes is blanched in hot water to increase the water content to 30 to 33 per cent, after which the prunes are allowed to stand overnight to cool and equalize in moisture content. They are then packed in transparent plastic bags or in such bags laminated to a paper outer bag; a measured volume of fumigant is added to each bag, such as ethylene oxide

or propylene oxide, and the bag heat-sealed. The fruit so processed and packed is excellent for eating out of hand and is also quick-cooking. The fumigant sterilizes the fruit and bag but disappears after the bag is sealed.

The same size grades prevail in Oregon as in California.

Christie processed six different lots of dehydrated prunes in water and steam to obtain data on the relative rates of moisture absorption in the two media, as shown in Table 47.

TABLE 47. RELATIVE RATES OF ABSORPTION OF MOISTURE BY PRUNES PROCESSED IN BOILING WATER AND IN STEAM

Lot no.	Moisture, per cent in original prunes	Percentage of moisture							
		Minutes in hot water			Minutes in steam				
		2	4	6	2	4	6	8	10
1	17.3	....	....	....	20.3	20.7	21.5	22.4	23.3
2	21.4	23.0	24.9	28.6*	....	22.9	....	24.2	
3	21.9	24.1	26.9†	30.7*	22.9	23.3	23.9	24.5	25.9
4	21.6	28.3†	29.5*	31.3*	23.9	25.2	25.6	26.1	27.0†
5	21.5	24.9	26.8†	27.8*	23.0	23.2	24.0	25.0	25.1
6	16.8	21.0	23.0	25.0	18.6	20.0	20.3	21.1	21.5

* Very moldy. † Trace of mold.

SOURCE: After Christie.

Storage tests showed that prunes of a moisture content of 28.6 to 30.7 per cent became moldy and that those of 25 per cent moisture did not mold.

Moisture absorption was more rapid in water than in steam.

Juice. A large part of the prune crop is utilized for the production of canned and bottled prune juice, a water extract of dried prunes prepared as described in Chapter 12. The prunes used for the production of juice are dry-cleaned, sorted, washed, and processed in much the same manner as for packing the dried fruit.

PACKING OF RAISINS

The mechanical equipment used in preparing and packing raisins has been brought to a high state of development.

Bulk-packed raisins and most of the carton-packed raisins are handled throughout by machinery; only certain kinds of carton goods and layer raisins are packed by hand.

Receiving. The raisins are delivered in sweatboxes holding about 150 lb. of raisins each. The raisins are usually sampled, and a moisture test is

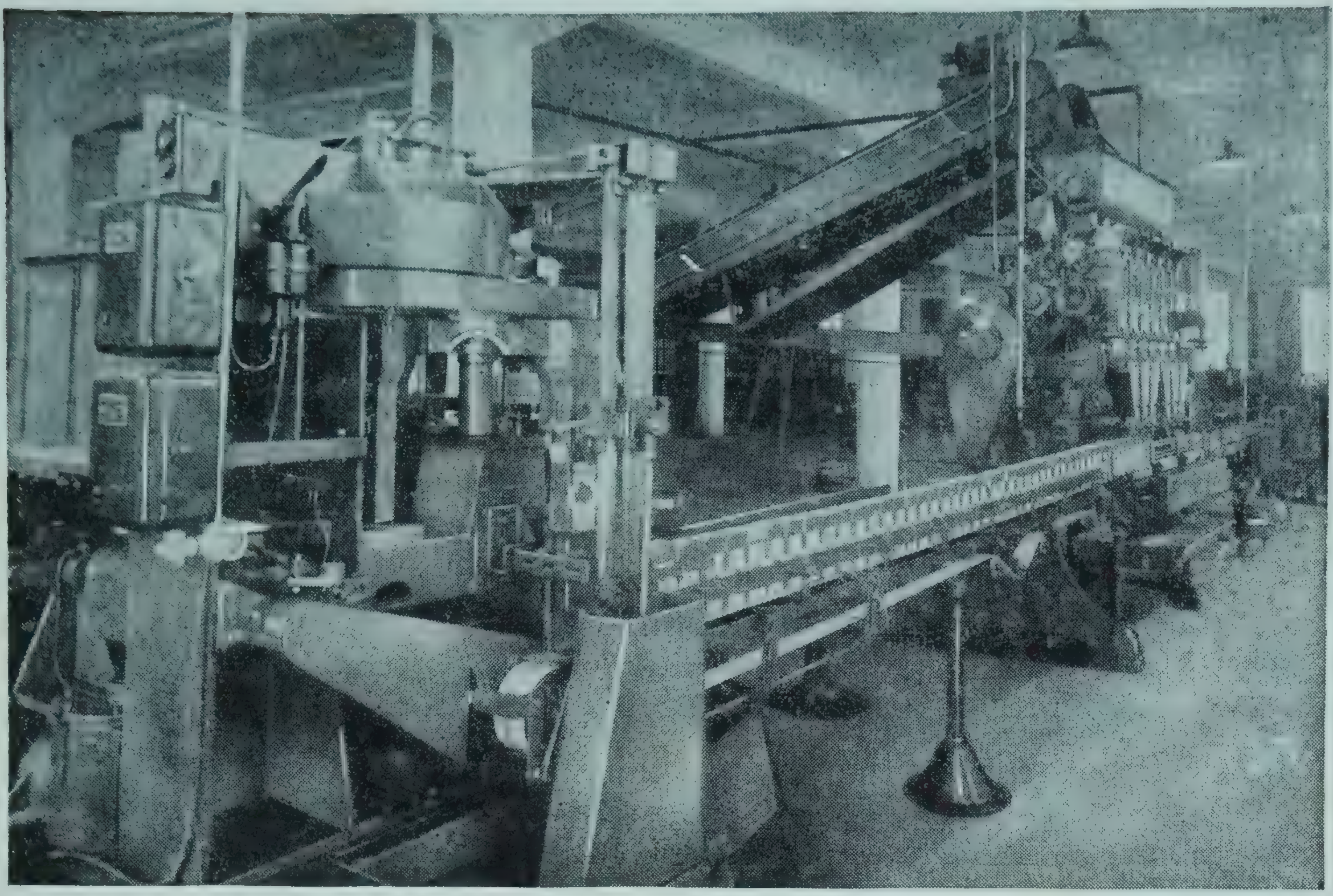


FIG. 97. Raisin-packaging line. *Left:* Carton-forming machine. *Right:* Filling spouts. Peloian Packing Co., Dinuba, Calif. (*Modern Packaging.*)

made. The packer desires the raisins to contain not more than 16 per cent of moisture, because if the moisture content is excessive it is very difficult to remove the stems. Nichols invented a simple device for measuring the moisture content of raisins by measuring their compressibility under standard conditions. However, the moisture content is now determined by the electrometric moisture apparatus of the California Dried Fruit Association, less than 3 min. being required for each determination. Means are also available for determining the sand content, per cent of moldy raisins, and degree of insect infestation (see section at end of chapter).

Processing and Packing Seedless Raisins. Thompson seedless raisins now constitute the major portion of the raisin output in California. The principal outlets at present are to the baking trade, the household trade, and for export; some also are used in the candy industry. Most of the crop is processed and packed in the San Joaquin Valley in and around the city of Fresno.

The growers dry most of the grapes in the sun and deliver them to the packers in 150-lb. so-called sweatboxes. Part of the deliveries is processed and packed as received, but a large proportion is stored for packing later. The sweatboxes of raisins that are to be stored are stacked about 30 boxes high by lift truck and covered with heavy building paper or tarpaulins in such a manner that a reasonably gastight enclosure is secured. The raisins are then fumigated very thoroughly with methyl bromide and left covered

until needed for packing. Fumigation is required by the Federal and state food and drug administrations.

The processing and packing operations in one modern plant are about as follows: The sweatboxes of raisins are emptied by automatic dumper into a hopper, from which they are elevated to a shaker screen that sifts out sand and other fine debris as a strong blast of air from a fan blows away leaves, some of the loose stems, and other trash. As much as 5 to 6 per cent of sand, leaves, and other waste is removed in this operation.

Next, the raisins pass through a stemmer which consists of a stationary outer screen and inner, rapidly revolving concave. The large stems ("bunch stems") are separated from the raisins between the stationary and the moving members. Some of the stems are removed and discarded at this point, but a large proportion of them are left with the raisins to assist in cap stemming.

In the cap stemmer the individual short stems attached to each raisin are rubbed off between a vertical, stationary truncated conical screen and a rapidly revolving inner screen.

Beyond the cap stemmer the raisins pass through a large revolving screen inside which projecting wire fingers pick up and remove the large stems and a powerful blast of air blows away the cap stems, fragments of the large stems, and the "red berries," that is, the immature raisins of light weight.

A shaker screen next removes fines and much of the remaining waste. A second revolving screen and powerful air blast repeat the cleaning operation. The final "dry-cleaning" operation is by shaker screen.

The dry-cleaned raisins are next size-graded by machine similar in operation and appearance to a fresh-pea size grader; generally two sizes are made, Extra Choice (the larger raisins) and Bakers' Seedless (the smallest sizes).

They are next transported in water by special pump to a riffle cleaner in which the raisins are floated over the riffles (baffles) and heavy foreign objects such as small stones, bits of glass, tramp iron, etc., sink and are removed. The raisins are thoroughly washed in the pumping, fluming, and riffling operations and absorb some water, the desired objective being about 16 to 16½ per cent H_2O. Water and raisins are separated in a dewatering screen reel and are thoroughly drained on their way to the packaging stations. The thoroughly drained raisins are delivered to overhead hoppers from which they are fed by gravity to package-filling machines.

The raisins are measured by volume into small cartons which are then closed by machine. The cartons are purchased in "knocked-down" (flat) form and are opened by machine at the packing station. After being closed by machine the filled cartons are overwrapped by another machine with lithographed paper wrappers, or cellophane, or metal foil. This packaging

line has a capacity of over 300 cartons per minute. Larger cartons are filled by weight (Figure 97).

For the baking trade and many other large industrial users of raisins the fruit is packed in 30-lb. fiberboard cases by weight, the raisins pressed into place by machine, the flaps glued, and the cases sealed by a continuous automatic case-gluing and closing machine such as shown in Figure 98. For overseas use by the military forces the raisins are usually packed in No. 10 cans, a small amount of liquid fumigant is added by automatic dispenser, and the can is sealed.

The raisins that are packed in small cartons are cased in fiberboard boxes, which are then sealed as previously outlined. All cases and cartons of packed raisins are placed in a gastight room or fumigation tank and fumigated with methyl bromide very thoroughly in order to make certain that no living insects or their eggs are in the packed products. The fumigating rooms are in a separate building at some distance from the processing and packing plant. Fumigation is not only a necessary precaution and a form of insurance against future claims or spoilage, but also is required by the Federal and state food and drug departments.

The waste stems are sold to be ground and mixed with other materials for use as a feed for livestock, and the "red berries" removed by air blast from the sound raisins are usually sold to a distillery for production of high-proof brandy used in fortifying sweet wines, or they may be used in mixed stock feeds.

Seedless raisins are classified according to the method used in drying the fresh grapes: "natural" (dried in the sun without lye dipping or sulfuring), "golden-bleached" (lye-dipped and sulfured in the fumes of burning sulfur, followed by dehydration), and "soda-dipped" (dipped in dilute NaOH solution followed by drying in the sun).

Processing and Packing Muscat Raisins. Muscat raisins are much larger in size than Thompson Seedless and have large seeds. The receiving, storage in sweatboxes, and laboratory examination of Muscat raisins are the same as described for Thompson Seedless raisins. After cleaning and stemming (removal of the large "bunch" stems), Muscat raisins are dried and capstemmed and then graded into the following sizes:

One-crown, $^{13}/_{32}$ in. in diameter
Two-crown, $^{17}/_{32}$ in. in diameter
Three-crown, $^{21}/_{32}$ in. in diameter
Four-crown, over $^{21}/_{32}$ in. in diameter

These sizes apply to the unseeded, loose raisins or layer (on-the-stem) raisins and the seeded raisins. Some Muscat raisins are packed unstemmed in special, shallow cardboard cartons holding several pounds. These are

known as layer raisins. While this style of packing is very common in Spain, relatively few raisins are packed in this manner in California.

Layers are classified, according to size of the berries and bunches, as Vineyard Run, Three-crown Layers, Four-crown Clusters, and Six-crown, or Imperial, Clusters. The Three-crown Layers are the smallest and Six-crown, or Imperial, the largest in size.

Muscat raisins cannot be cap-stemmed satisfactorily unless they are dried to less than 12 per cent of moisture.

In one of the large driers the raisins are fed mechanically on the topmost woven-wire draper of the drier, which is about 10 ft. wide and about 50 ft. long, and are spread to give a load of about 5 lb. per sq. ft. The initial temperature on this draper is about 120°F. The draper carries the raisins slowly to the opposite end of the drier and drops them to the draper immediately below. The raisins traverse the length of the drier seven times during drying, the temperature increasing as they progress until they reach 165 to 180°F.

Heat is furnished by heated air blown upward through the drapers of raisins by a powerful multivane fan.

The raisins are delivered by the lowermost draper to a cooling draper, on which they are chilled by an upward blast of cold air. This hardens them by increasing the viscosity of the invert-sugar sirup in the raisins and gives them sufficient rigidity to withstand cap stemming. The drying time is about 5 hr.

Only Muscat, Malaga, and other large varieties of raisins require the drying process described above. Thompson Seedless and Sultana varieties can be cap-stemmed without such drying. Muscat raisins are cap-stemmed in the same manner as the Thompson Seedless, as previously described.

The cap-stemmed raisins pass over a screen and through a blast of air, which process separates them from the dislodged cap stems.

The one-crown, i.e., smallest-size, Muscat raisins are not seeded. They contain, as they come from the stemmer, many light immature dried berries. These immature and worthless raisins are removed by flotation in water or by air blast.

The larger sizes of cap-stemmed Muscat raisins are generally seeded. The raisins are first treated in water (at about 200°F.) and steam to soften them and to return the moisture removed in drying for cap stemming. The processor consists of a tank of heated water in which revolves a screen cylinder that carries the raisins through the water. The heating loosens the seeds and softens the pulp so that the seeds can be removed readily.

The seeder is equipped with four rolls, of which two consist of rubber, one of very fine-toothed circular saws, and one of very coarse circular saws. The fine saws are known as the "seeder rolls," and the coarse saws as the "flicker rolls." The rubber rolls press the raisins against the revolving fine-

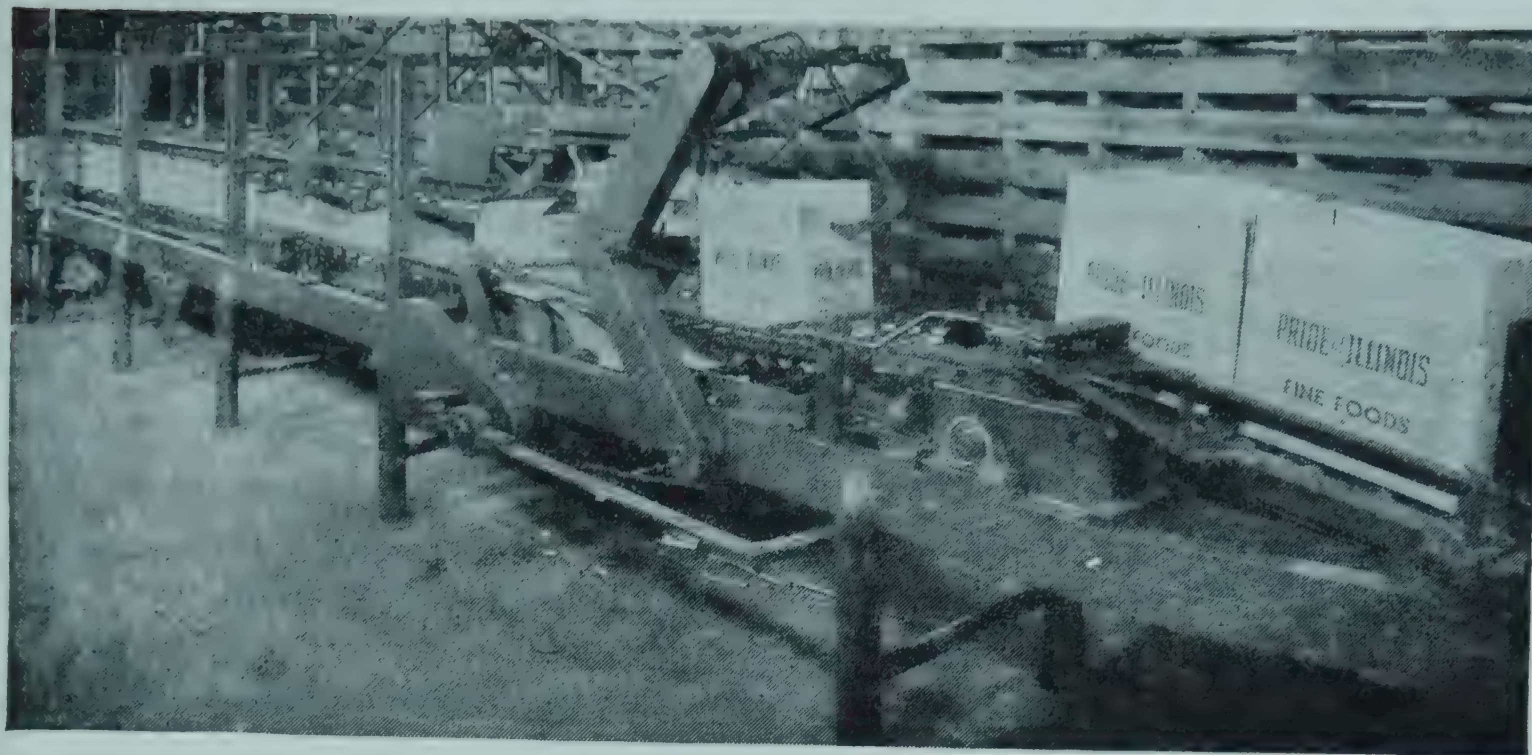


FIG. 98. Automatic gluing and sealing machine for fiberboard cases. (*Western Canner and Packer.*)

toothed circular saws (the seeder rolls). The flesh of the raisins is pressed into the saw teeth. The seeds remain on top of the saws and are removed by the coarse saws. Rubber rolls next force the raisins between metal fingers so adjusted that the soft raisins pass between them and the hard seeds are caught and removed. Fourteen seeders handle the output of ten continuous driers, or approximately 40 tons of raisins per hour, in one large California plant.

Seeding has greatly increased the popularity of Muscat raisins and has made possible their use in baking, confectionery, ice cream, and in general cookery. In the Raisin Association's plant most of the seeded Muscat raisins are treated by a secret process with highly refined raisin-seed oil to prevent the sticking together of the raisins.

Packing. The hot, seeded Muscat raisins direct from the seeder are packed into 12- and 15-oz. cartons or into fiberboard boxes holding 30 and 50 lb. for the baking trade and other large users. The boxes are lined with heavy waxed paper, which retards evaporation of moisture and facilitates emptying the containers. Retarding of evaporation reduces the tendency of the raisins to "sugar" in the box during storage.

Some Thompson Seedless raisins are packed in very small cartons holding 1½ oz. each. They are used in lunches and as between-meal snacks.

Other Packages. Seeded Muscat raisins were at one time also packed in cans for shipment to the tropics, and in this form are proof against spoilage. The recommended process consists in increasing the moisture content of the seeded raisins to 30 per cent, canning, exhausting 15 min. at 200 to 212°F., sealing, sterilizing at 212°F. for 25 min., and cooling. The 8- and 12-oz. cans are preferred.

Layer raisins, as previously indicated, are packed very carefully into

shallow cartons for dessert use. They are also frequently used in fancy mixed packs of raisins, nuts, figs, and peaches for the holiday trade (see paragraph on grading for different grades of layer raisins).

Fumigation. Seedless raisins are not heated before packing and hence should be fumigated, in the final insectproof package as well as before processing. A small amount of propylene oxide or a mixture of ethylene oxide and ethylene dichloride may be added to each package.

The seeded Muscat is not so liable to infestation because it is sterilized effectively by heat during drying for cap stemming and again during the seeding process.

PACKING DEHYDRATED VEGETABLES

During the First World War it became necessary to develop methods of packing that would protect dehydrated vegetables against insects and moisture.

Effect of Moisture. Vegetables must be dried to a low moisture content, and the package must protect them against absorption of moisture; otherwise the vegetables discolor and rapidly deteriorate in flavor. Their moisture content should be maintained below 5 per cent.

Unless dried to very low moisture content dried vegetables deteriorate rapidly. Most varieties are dried to less than 4 per cent moisture content. Howard and others have recommended placing in the package anhydrous lime or other desiccant to reduce the moisture content to a very low level, thus greatly prolonging the storage life of the product.

Packages. Nichols found that a tightly sealed carton is satisfactory for storage of dried vegetables in an arid climate but unsuitable for use in a moist climate, because under the latter condition moisture penetrates the package readily, even if paraffined, and increases the moisture content of the vegetables to the point where rapid deterioration ensues. Rabak and others have greatly extended Nichols's findings. Some of the changes are enzymic, others purely chemical. Heavy cellophane-laminated heat-sealed aluminum bags are very successful. These are familiar to housewives as packages for dried soups.

Friction-top cans were found to be reasonably resistant to moisture absorption and relatively inexpensive and convenient. For use of the United States Army, the vegetables were sealed by double seaming in 5-gal. cans. These cans are satisfactory but more expensive than cartons and less convenient than friction-top cans. Vacuum packing has been found to improve the keeping quality of dehydrated vegetables greatly. During the Second World War dried carrots and cabbage were packed in carbon dioxide gas in 5-gal. cans sealed by double seaming. Other dried vegetables

were packed in 5-gal. cans in air. Some were packed in multiwall, heat-sealed paper bags placed in heavy cartons of about 5-gal. size.

Recently, the addition of a desiccant, such as calcined lime in pellet form, to cans of dried vegetables has been found very effective in lowering the moisture content of the product and thus retarding deterioration. The research on this method was done at the Western Regional Research Laboratory, Albany, California.

Fumigation. Dried vegetables, unless dried to very low moisture content and packed in airtight containers immediately after drying, should always be fumigated or otherwise treated to render them free of insect life if they are stored in bulk. Cartons and boxes must be also fumigated before packing, as they may carry insect eggs. Vacuum fumigation of the carton-packed product has been used.

Heat-treatment. Heating to 145 to 160°F. for 2 to 3 hr. will kill the insects and their eggs after packing; or a shorter heating of the dried vegetables on a metal-cloth conveyer will suffice.

Darkening of Dried Fruits. On prolonged storage dried fruits, particularly apricots, peaches, and prunes, darken in color and their flesh eventually becomes black. Molasses, fruit concentrates, and some other food products of high sugar content undergo similar darkening. As pointed out by Long, Mrak, and Fisher, darkening of cut fruits such as apricots is greatly delayed if a high content of SO_2 in the fruit is maintained, in the neighborhood of 2,000 p.p.m. This darkening has been shown to be separate and distinct from browning of the flesh of fresh-cut fruits by enzymic oxidation of phenolic substances in the fruit tissue. Maillard (1916) was probably the first to discover that at least one form of the darkening reaction involves reaction between amino acids of the food product, such as molasses, with hexose sugars, such as dextrose and levulose. In the Food Technology Department of the University of California, Mackinney and his associates have conducted much research on the darkening of dried fruits and fruit concentrates.

Weast and Mackinney (1941) arrived at the following findings and conclusions in regard to the darkening of dried apricots. The black compound was readily dissolved from blackened apricots by 50 per cent acetone (in water) but not by 95 or 75 per cent ethyl alcohol. It was precipitated from the 50 per cent acetone solution by addition of sufficient acetone, or by strongly acidifying with an inorganic acid or by adding lead acetate. The first two methods are preferred to the third because of the difficulty of deleading the precipitate. Electrodialysis was used to remove ash-constituent impurities. Repeated dissolving of the precipitate and re-precipitations plus electrodialysis gave a product which on evaporation to dryness *in vacuo* was shiny black in color and noncrystallizable by ordinary techniques. A yield of about 5 per cent by weight of the purified

black compound was obtained from dried apricots of maximum black color. It contained 3.26 per cent nitrogen, which the authors state may be derived from aspartic acid. A black compound (or perhaps series of them) was obtained by reactions between dextrose or levulose and aspartic acid (an amino acid). Glutamic acid also reacted with these sugars in a similar manner. Levulose reacted more rapidly than dextrose. The authors conclude that severe dehydration occurs during the reaction; that a rigid differentiation of darkening of sugars by caramelization and by the amino acid and sugar reaction of Maillard does not appear practicable under natural conditions, but that the Maillard reaction does play an important role in the darkening of dried fruits, fruit concentrates, and possibly many other food products.

Subsequently E. R. Stadtman, Barker, Mackinney, Haas, F. Stadtman, Mrak, Natarajan, Temmer, Wahab, and others have continued the studies at the University of California on the darkening reactions and on the darkening of cut dried fruits in storage. The formation of furfural and hydroxymethylfurfural has been demonstrated as occurring during the darkening of dried apricots and can act as intermediates in darkening. F. Stadtman found in addition to the furfurals at least 13 other carbonyl compounds extracted from blackened apricot sirup by continuous extraction with ethyl acetate. Haas, E. R. Stadtman, F. Stadtman, and Mackinney (1948) reported that continuous extraction of apricot concentrates with ethyl acetate prevented darkening by removing furfurals as rapidly as they were formed; addition of furfural to the concentrate markedly increased the rate of darkening; the dark compounds produced by addition of furfural were indistinguishable spectrophotometrically from those produced in the natural browning of the fruit; and formaldehyde prevented both furfural and natural darkening. It was shown also that sugars are involved in the formation of furfurals.

Haas and E. R. Stadtman showed that darkening reactions can occur between the nitrogenous constituents of the fruit and sugars, between the nitrogenous substances and organic acids, between sugars and organic acids, and in reactions involving organic acids only. Cruess (unpublished data) found that when ascorbic acid was added to white wine and the wine stored at a warm temperature, 80 to 85°F., the color remained light for several months and then darkened rapidly, eventually becoming black; whereas the untreated wine did not darken. Evidently nonenzymic darkening is complex and involves several different reactions.

Dried-fruit packers often store dried fruits under refrigeration in order to retard darkening.

U.S. Grades for Dried Fruits. The U.S.D.A., Agricultural Marketing Administration, also known as the Production and Marketing Administration, has established standards and specifications for dried fruits. It

is not possible to present these in detail or for all dried fruits, but sufficient will be given to indicate their principal features for two fruits and their general application to others.

The following definitions and specifications are given in the U.S.D.A., Agricultural Marketing Administration, publication on grades for processed raisins (Aug. 26, 1955). Although the size of Thompson Seedless raisins is not incorporated in the grade specifications as a factor in determining quality, the common size designations are given. Select size means that not less than 35 per cent by weight of the raisins and not more than 85 per cent will pass through round perforations $^{24}/_{64}$ in. in diameter, but not more than 5 per cent may pass through perforations $^{20}/_{64}$ in. in diameter. Small, or Midget, raisins are of such size that all will pass through circular perforations $^{24}/_{64}$ in. in diameter and not less than 90 per cent through perforations $^{20}/_{64}$ in. in diameter. Mixed size signifies a mixture that does not meet the requirements for Select size.

U.S. Grade A Thompson Seedless, or U.S. Fancy, must possess similar varietal characteristics, a good color, and good flavor, characteristic of raisins prepared from well-ripened grapes, contain not more than 18 per cent of moisture by weight, and meet the following additional requirements: The raisins must not contain more than one piece of stem per 32 oz.; not more than 15 cap stems per 16 oz.; not more than 1 per cent by weight of immature raisins (blow-overs); not more than 2 per cent of damaged raisins; not more than 5 per cent of sugared raisins; not more than 2 per cent by weight of moldy raisins; no damage by fermentation; no sand or grit of any consequence that would affect appearance or edibility.

U.S. Grade B, or U.S. Choice, Thompson Seedless raisins possess similar varietal characteristics, reasonably good typical color, and good characteristic flavor; they must be prepared from reasonably well-matured grapes and contain not more than 18 per cent by weight of moisture. The additional requirements are somewhat less severe than for U.S. Grade A.

The requirements for Grade C, or U.S. Standard, are less rigorous than for U.S. Choice, but the raisins must not have more than 18 per cent of moisture, and they must possess a fairly good flavor and color. Substandard raisins are those that do not meet the requirements for U.S. Grade C.

The requirements for U.S. grades for Muscat raisins are also given in the specifications. They are similar to those for Thompson Seedless raisins. Moisture content of seeded Muscat raisins must not exceed 19 per cent, and layers not more than 18 per cent.

U.S. Grade A, or U.S. Fancy, dried prunes possess similar varietal characteristics. Not more than 10 per cent by weight of the prunes may be affected by defects 1 to 10 mentioned in the following list, provided, further, that not more than two-fifths of the total tolerance, or 4 per cent

by weight, of all the prunes may be affected by defects 9 and 10, and not more than one-tenth of the total tolerance, or 1 per cent by weight, may be affected by defect 10. The various defects are: (1) skins of off color (not blue-black, black, reddish purple, or other characteristic color). (2) Prunes of flesh color darker than Mirador Brown of Maertz and Paul. (3) Prunes possessing air pockets, or porous, woody, fibrous, or immature flesh. (4) Prunes possessing flesh damaged by fermentation. (5) Certain skin defects such as growth cracks, splits, breaks in the skin, skin damage from overdipping, rain, processing, or other causes that materially affect the appearance. (6) Scabby prunes having tough or thick scab exceeding in aggregate area 3/8 in. in diameter, or scab of other type exceeding in the aggregate in area that of a circle 3/4 in. in diameter. (7) Damage from scorching during sun drying or dehydration sufficient to materially damage the skin or flesh. (8) Insect injury or similar defects. (9) Mold, insect infestation (no live insects permitted), imbedded dirt, or other foreign material. (10) Prunes affected by decay.

For U.S. Grade B the total weight of all defective prunes is increased to 15 per cent and other requirements are somewhat less severe than for U.S. Grade A. For U.S. Grade C, or Standard, total defects must not exceed 20 per cent by weight. U.S. Grade D, or Substandard, must be wholesome and edible fruit that does not meet the requirements for Grade C. See U.S.D.A., Agricultural Marketing Administration, specifications for details.

Specifications have also been established and published for U.S. grades for other important dried fruits and may be had free of charge on application to the U.S.D.A., Agricultural Marketing Administration.

A point of considerable interest in the grade specifications and standards for dried fruits is the absence of a numerical scoring system such as those used for canned fruits, tomato products, and some other food products.

LABORATORY EXAMINATION OF DRIED FRUITS

Because the food administration and the packers have adopted rather stringent standards for dried fruits in respect to presence of mold, rot, sand, and insects or insect damage, it has become necessary for packers to make certain tests, or to have them made, upon the dried fruit as received and upon the packed fruit. Cut fruits (apricots, peaches, pears, and apples), raisins, and fig paste are particularly apt to show insect infestation, insect parts, or other evidence of insect damage.

Sampling Unprocessed Dried Fruit. A handful should be taken from each of several boxes or from several locations in the bin of fruit, including positions several feet beneath the surface, or samples may be taken from

the grader or conveyer belt. The samples should be well mixed and an average sample taken for examination.

Moisture. Some of the sample may be ground in a simple, inexpensive kitchen-size food grinder, first with the bladed knife and then with the nut-butter attachment.

A weighed sample of 4 to 5 grams may be dried in a shallow aluminum dish in a vacuum oven 12 to 14 hr. at 70°C. The loss in weight is moisture. Or the moisture may be determined by determination of conductivity of the sample by a special instrument invented by C. D. Fisher and obtainable through the California Dried Fruit Association, San Francisco. Instructions and tables accompany the instrument. Properly used, it is remarkably accurate and rapid in operation.

Moisture may be determined approximately by distillation of a 50-gram sample with xylene or toluene (see reference to Nichols and Reed).

Drying at 100°C. is subject to serious error owing to decomposition of levulose to carbon dioxide and water at that temperature.

Sand in Raisins. A sample of 250 grams of the finely ground raisins is thoroughly mixed with 2 qt. of water and boiled several minutes with stirring to break up lumps. The lighter ground-raisin flesh is floated off carefully in a stream of water. Saturated brine is then added, and the material that floats is skimmed off. The residue is "panned," i.e., gently agitated in a shallow pan with the brine until the sand is free of raisin particles. It may then be filtered on an ignited Gooch crucible, dried, ignited, and weighed; or may be measured by volume in a Dried Fruit Association sand tube. The sand content should not exceed seven units measured in this tube.

A routine receiving test at the packing plant consists in passing a large sample through an air-blast and screen-cleaning machine and weighing the sand and other waste separated from the sample by the machine.

Mold and Rot in Raisins. Two samples of 100 berries each are placed in saucers of 3 per cent hydrogen peroxide. Areas attacked by mold or rot cause evolution of oxygen gas because of the presence of a catalase formed by the mold. However, if the raisins have been steamed, as for seeding of Muscat raisins, the catalase is destroyed, and then even moldy raisins will give a negative test. The total of mold- and insect-damaged raisins should not exceed 10 per cent, or 8 per cent if the sand content is high.

Insect Damage. For raisins the test consists in rolling a number of individual raisins between the fingers beneath water in a white dish and examining for presence of pellets (excreta) and insects or insect parts. The rubbing should be severe enough to dislodge pellets or insects that may be present beneath the skin. Often also badly attacked raisins will

be evident to the eye or by aid of a hand lens; portions of the skin may be eaten away, or pellets and webbing may be evident.

At least 50 specimens of cut fruit such as peaches, apricots, pears, or nectarines should be examined. Usually insects and insect damage are evident to the unaided eye or with a hand lens. Infestation is of two types, viz., that occurring on the tree from such insects as codling moth and peach twig borer and that occurring during or subsequent to drying. Any piece is classified as infested if insects, dead or alive (larvae, pupae, or adults), or their excreta are present.

Peaches and pears will usually show heavier infestation than apricots owing to attack of the fruit by codling moth (pears) and borer (peaches) on the trees.

Growers should discard wormy fruit and should not dry it. Packers should sort all dried fruit carefully under rather intense light on slowly moving belts in order to remove all or nearly all the infested pieces. It should be feasible to reduce the number of infested pieces below 3 per cent.

A weighed sample of fig paste may be heated with sodium hydroxide solution to dissolve and remove most of the fruit tissue. Worm and insect heads and other chitinous parts of the insects are not destroyed. They can be identified by examining under a low-power microscope for insect fragments, much as the presence of worm fragments in tomato products is determined. The number of worm or insect heads per standard weight of paste is counted. Details of the test may be had from the Dried Fruit Association, San Francisco or Fresno, California, and from the Food and Drug Administration, Washington, D.C.

Other Determinations. The total sulfur dioxide content of cut fruits is often determined by distillation of a 50-gram sample, mixed with water and a few cubic centimeters of hydrochloric or phosphoric acid, into standard iodine solution and titrating the excess iodine with $N/10$ thiosulfate (see Association of Official Agricultural Chemists, "Official and Tentative Methods of Analysis," 1955, for details).

Total sugars and total reducing sugars are determined by the standard gravimetric Munson-Walker method, by the Shaffer-Hartmann method, or by other accurate volumetric method.

Other determinations are seldom made.

REFERENCES

Barger, W. R.: Effect of cold storage conditions on the keeping quality of dried fruit, *Frozen Foods Recorder*, **33**(6), 47–50, May, 1941.

Beekhius, W. H.: "Observations on dried fruits and raisins," California Dried Fruit Association, San Francisco, March, 1939. Mimeographed report.

California Dried Fruit Association: Rodent control, July, 1946. Mimeographed circular.

Christie, A. W., and Woodworth, C. E.: The relation between insect growth and moisture in dried fruits, *Western Canner and Packer*, **15**(5), 8–10, 1923.

Cruess, W. V., and Balog, E. G.: Dried fruit cold storage tests, *Western Canner and Packer*, **38**, August, 1946.

——— and Mackinney, G.: Dehydration of vegetables, *Univ. Calif. Agr. Expt. Sta. Bull.* 680, September, 1943.

——— and Musco, D. D.: Date products investigations, *Ann. Date Growers' Inst. Proc.*, Indio, Calif., 1952.

Essig, E. O.: Important dried fruit insects in California, *Calif. State Dept. Agr. Suppl. Monthly Bull.*, **9**(3), 119–125, March, 1920.

——— and Hoskins, W. M., Michelbacher, A. E., and Smith, R. F.: A report on the penetration of packaging materials by insects, *J. Econ. Entomol.*, **36**(6), 822–829, 1943.

Haas, V., Stadtman, E. R., Stadtman, F. H., and Mackinney, G.: Deterioration of dried fruits, I, *J. Am. Chem. Soc.*, **70**, 3576, 1948.

——— and Stadtman, F. H.: Use of ion exchange resins to identify types of compounds involved in browning, *Ind. Eng. Chem.*, **41**, 983, 986, May, 1949.

Harper, L. K.: Packaging of dehydrated foods, *Canning Age*, **23**(6), 318–320, 1942.

Hendel, C. E., and Legault, R. R.: Observations on rate of in-package desiccation, *Food Technol.*, **8**(4), 189–191, April, 1954.

How to clean a raisin, *Western Canner and Packer*, **47**(5), 22–27, May, 1955.

Howard, B. J.: Testing cut dried fruits, *U.S. Dept. Agr., Food and Drug Admin., Microanal. Div., Pub.* 4, 1935.

———: Fig testing U.S. Dept. Agr., Food and Drug Administration, July, 1929. Mimeographed manual. Laboratory examination of dried figs.

Joslyn, M. A., and Marsh, G. L.: Browning of orange juice, *Ind. Eng. Chem.*, **27**, 186, 1935.

Linsley, E. G., and Michelbacher, A. E.: Insects affecting stored dried products, *Univ. Calif. Agr. Expt. Sta. Bull.* 676, March, 1943.

Mackinney, G., and Temmer, O.: The deterioration of dried fruit. IV. Spectrophotometric and polarigraphic studies, *J. Am. Chem. Soc.*, **70**, 3586–3590, 1948.

Maillard, L. C.: Reactions between sugars and amino acids, *Ann. Chim.*, **5**, 258, 1916.

Makower, B., and Dehority, G. L.: Equilibrium moisture content of vegetables, *Ind. Eng. Chem.*, **35**, 193–197, 1943.

"Methyl Bromide: A Fumigant," Dow Chemical Company, San Francisco, 1940.

Methyl bromide as a fumigant, *Calif. State Dept. Agr. Monthly Bull.*, **34**(1), 4–14, 1945.

Meyers, J. G.: "Report on Insect Infestation of Dried Fruit," Empire Marketing Board, H. M. Stationery Office, London, 1928.

Michelbacher, A. E., and Ernst, F. H.: The storage and protection of dried food products for home use, *Univ. Calif. Agr. Ext. Serv. Circ.*, 1943.

Microanalysis of food and drug products, *U.S. Dept. Agr., Food and Drug Admin., Microchem. Div., Circ.* 1, 1944.

Mrak, E. M., and Stadtman, T.: Microbiological deterioration of dried fruits, 23*d* *Ann. Date Growers' Inst. Proc.*, Indio, Calif., April, 1946.

Neuman, W. K., Wilson, R. V., and Van Wazer, F. P.: Recent developments in the packaging and storage of dried foods, *Proc. Inst. Food Technol.*, 1944, pp. 42–53. See also *Food Inds.*, **16**(3), 63, March, 1944.

Parker, W. B.: Control of dried fruit insects in California, *U.S. Dept. Agr., Bull.* 235, 1915.

Prater, A. N., Johnson, C. M., Pool, M. F., and Mackinney, G.: Determination of sulfur dioxide in dehydrated foods, *Ind. Eng. Chem., Anal. Ed.*, **16**, 153–157, 1944.

RUSHTON, E.: Compressed dehydrated vegetable blocks, *Chemistry & Industry*, Sept. 1, 1945, pp. 274–276.

SIMMONS, P., BARNES, D. F., DONOHOE, H. C., and FISHER, C. K.: Progress in dried fruit investigations in 1935, *U.S.D.A.*, *Bur. Entomol.*, *Rept.* E-382, 1936. Mimeographed. Insect control.

STADTMAN, F. H.: Deterioration of dried fruits, III, *J. Am. Chem. Soc.*, **70**, 3583, 1948.

———, BARKER, H. A., HAAS, V., and MRAK, E. M.: Influence of temperature on deterioration of apricots, *Ind. Eng. Chem.*, **38**, 541–543, May, 1946.

———, ———, MRAK, E. M., and MACKINNEY, G.: Influence of moisture and sulfur dioxide on the deterioration of dried apricots, *Ind. Eng. Chem.*, **38**, 98–104, January, 1946; **38**, 324–329, March, 1946.

THOMPSON, J. B.: Comparison of methods of determining sulfur dioxide in dehydrated vegetables, *Proc. Dried Foods Conf.*, *Subsistence Research Lab.*, Chicago, January 31, 1945, pp. 25–27.

U.S. Department of Agriculture, Agricultural Marketing Administration: U.S. standards for grades of processed raisins, Aug. 26, 1955. See also similar publications on standards for grades of dried apples, apricots, currants (small dried Corinth varieties of grapes), figs, peaches, pears, and prunes.

Vegetable and fruit dehydration, *U.S. Dept. Agr.*, *Bur. Agr. Ind. Chem. Misc. Pub.* 540, June, 1944.

Unusual convenience items are low moisture fruits, *Western Canner and Packer*, **47**(12), November, 1955. Vacuum-dried fruits.

VON LOESECKE, H. W.: "Drying and dehydration of foods," Reinhold Publishing Corporation, New York, 1943.

WAHAB, A.: Deterioration of dried fruits, II, *J. Am. Chem. Soc.*, **70**, 3580, 1948.

WEAST, C. A., and MACKINNEY, G.: Nonenzymatic darkening of fruits and fruit products, *Ind. Eng. Chem.*, **33**, 1408–1412, 1941.

WHELTON, R., PHAFF, H. J., MRAK, E. M., and FISHER, C. D.: Control of microbiological spoilage by fumigation with epoxides, *Food Inds.*, **18**, 23–25, 174–176, 318–320, 1946.

CHAPTER 21

VINEGAR MANUFACTURE

The manufacture of vinegar provides a means of utilizing a large proportion of the cull fruit from apple-packing establishments and the peels and cores from apple driers and canneries. Other cull fruits, such as oranges, grapes, prunes, peaches, pears, pineapples, bananas, and starchy vegetables, such as sweet potatoes, can also be utilized for vinegar manufacture.

Definitions. Vinegar may be defined as a condiment made from various sugary and starchy materials by alcoholic and subsequent acetic fermentation.

Cider Vinegar. The Pure Food and Drug Act of the United States defines cider vinegar or apple vinegar as "the product of alcoholic and subsequent acetous fermentation of the juice of apples." According to the pure food and drug regulations, the word "vinegar" unqualified can be applied only to vinegar made from apples. However, the word "vinegar" is derived from the French *vinaigre* (sour wine).

Cider vinegar is levorotatory. It contains at least 4 grams of acetic acid per 100 cc. and at least 1.6 grams of apple solids per 100 cc., of which not more than 50 per cent are reducing sugars. It must be stated, however, that most of the cider vinegar on the market need not conform to these standards, for the reason that it is diluted with water and the label on the container bears a statement to that effect. Diluted cider vinegar must contain at least 4 grams of acetic acid per 100 cc. but need not conform to the other standards noted above.

Grape vinegar, or *wine vinegar,* is made by the alcoholic and subsequent acetous fermentation of the juice of grapes and must, at 20°C., contain more than 1 gram of grape solids, more than 0.13 gram of grape ash, and at least 4 grams of acetic acid per 100 cc.

Spirit vinegar (distilled vinegar, grain vinegar) is the product made by the acetous fermentation of dilute distilled alcohol and contains, in 100 cc. (20°C.), not less than 4 grams of acetic acid.

Miscellaneous Commercial Vinegars. In a decision by a court in the Eastern United States, vinegar made from the dried peels and cores may be labeled "apple vinegar from dried cores and peels," and the names

"cider vinegar" and "apple cider vinegar" are reserved for use in labeling vinegar made from the juice of the whole fresh fruit.

Any fruit that contains more than 9 per cent sugar can be converted into a vinegar which will contain more than the legal minimum of 4 grams acetic acid per 100 cc.

One of the largest sources of distilled vinegar is the waste liquor from the manufacture of compressed yeast. Starchy vegetables are sometimes used in the manufacture of distilled vinegar. This is particularly true in Germany, where potatoes are used for this purpose.

Relation of Fruit Vinegars to Horticulture. Where vinegar is produced on a large scale commercially, as in the case of apple vinegar, this manufacture acts as a balance wheel for the industry by absorbing much of the fruit that would otherwise appear on the market in competition with graded fruit, to the disadvantage of the latter.

Uses of Vinegar. In addition to its use on the table, one of the principal commercial uses of vinegar is in the manufacture of pickles. Large quantities are also used in the manufacture of tomato catsup, chili sauce, and sauces used in the canning of fish. It is also used in the manufacture of acetic acid and for the production of acetone, a solvent used in the manufacture of smokeless powders.

Preparation of Fresh Fruits. Juicy fruits, such as apples, grapes, and oranges, are usually crushed and pressed without preliminary fermentation of the crushed fruit before pressing.

Apples are grated and pressed as in the preparation of unfermented cider. The modern hammer-mill type of grinder should be used. The pomace contains a considerable amount of juice, a large proportion of which is recovered by grinding in an apple grater and pressing. A larger yield is obtained by placing the pomace in tanks and permitting it to ferment for 2 or 3 days before pressing. If this method is employed, 10 to 20 gal. of actively fermenting cider per ton of pomace must be added and mixed with the pomace in order to promote yeast fermentation and prevent acetification. If the pomace or other raw material acetifies (becomes vinegar-sour), the acetic acid will in many cases stop alcoholic fermentation and result in a partially fermented inferior vinegar. The juice expressed from the pomace should not be mixed with the juice from the whole apples because it is inferior in quality.

Grapes are crushed and pressed as for making white juice if white wine vinegar is to be made. However, if red wine vinegar is the objective, red wine grapes are crushed and the juice is fermented on the skins to extract the color. A common raw material is dry red wine that has become slightly vinegar-sour in the commercial production of red wine.

Cull oranges once were used in a large factory in California for vinegar manufacture. The process formerly in use was developed by Chace and

Poore of the Citrus By-products Laboratory of the Bureau of Chemistry, U.S.D.A., in Los Angeles, Calif. The juice was expressed with large fluted bronze rolls. The fresh juice containing the orange oil from the skins was centrifuged for recovery of the oil, and the juice then was used for vinegar making.

Pears, peaches, apricots, fresh prunes, plums, ripe bananas, and other pulpy fruits should first be crushed and allowed to undergo alcoholic fermentation for several days before pressing, since preliminary fermentation facilitates pressing and increases the yield.

In order to facilitate pressing of the fermented fruit, a pectic enzyme should be added to the crushed fruit before fermentation. One to two grams of Pectinol O or W or an equivalent amount of other pectic-enzyme preparation per 1,000 grams of fruit has given excellent results experimentally.

Dried Fruits. Dried fruits contain from 50 to 70 per cent sugar. Enough water should be added to reduce the sugar content of the mixture to about 15 per cent, a starter of pure yeast added, and the mixture allowed to ferment until well disintegrated before pressing. The pressed juice may then be allowed to ferment dry and later acetified in the usual manner.

Preparation of Starchy Tubers, Etc. Starchy vegetables, such as potatoes, must be hydrolyzed with diastase or with dilute mineral acids before fermentation. The crushed vegetables are heated under pressure in a closed retort, or more slowly by boiling in water or by steaming at atmospheric pressure to gelatinize or dissolve the starch. The mixture must then be cooled to 60°C. if it is to be hydrolyzed with malt. Two to five per cent of ground malt should be added, mixed with the gelatinized mass, and stirred until the starch is converted to maltose by the following reaction (some dextrin also is formed):

$$\underset{\text{Starch}}{(C_6H_{10}O_5)x} + \underset{\text{Water}}{x(H_2O)} = \underset{\text{Maltose}}{x(C_{12}H_{22}O_{11})}$$

This process is known as "mashing," and the vessel in which the process is conducted is the "mash tun." It consists of a large circular tank equipped with a stirring device and open steam coils.

The progress of hydrolysis is observed by testing with iodine solution as follows: A drop of the mash is placed in a dish, and a drop of dilute iodine solution is added. If starch is still present, a deep-blue color is obtained. The starch may be hydrolyzed by use of an enzyme produced by a mold, e.g., such an enzyme as takadiastase.

Sweet potatoes normally contain 25 to 30 per cent total carbohydrates, of which starch forms the major proportion, and Irish potatoes usually contain from 16 to 22 per cent starch. Sweet potatoes produce a palatable vinegar without distillation, but because of the disagreeable flavor of

fermented Irish potatoes, vinegar is made from the alcoholic distillate of the fermented material.

The gelatinized starch may also be converted to fermentable sugar, in this case dextrose, by treatment in retorts under steam pressure with a dilute mineral acid, such as hydrochloric, and the acid neutralized with sodium carbonate, calcium carbonate, or sodium hydroxide after hydrolysis.

Honey. Low-grade honey unsuitable for table use may be utilized for making vinegar. The honey is diluted to about 15° Balling. Yeast food must be added in order to secure satisfactory fermentation. In the University of California Food Technology laboratory approximately 2 grams of potassium dihydrogen phosphate, 2 grams of ammonium sulfate, and 3 grams of citric acid per liter gave good fermentation.

Nature of Fermentation. The manufacture of vinegar requires two fermentation processes. The first of these is fermentation of the sugars to alcohol and carbon dioxide and is accomplished by yeast. The second fermentation results in the oxidation of the alcohol to acetic acid and is caused by vinegar bacteria. The reactions involved are shown by the following equations:

$$C_6H_{12}O_6 = 2CO_2 + 2C_2H_5OH$$
$$2C_2H_5OH + 2O_2 = 2CH_3CO_2H + 2H_2O$$

An intermediate step in acetification is the formation of acetaldehyde by the following reaction:

$$2C_2H_5OH + O_2 = 2CH_3CH{:}O + 2H_2O$$

Effect of Acetic Acid on Yeast. The two fermentations, alcoholic and acetic, cannot continue simultaneously for the reason that the acetic acid formed by the vinegar bacteria retards yeast growth and activity. Experiments made by the author prove that *Saccharomyces ellipsoideus* ceases growth and fermentation if the acetic acid concentration exceeds 0.5 per cent. This amount of acid is often formed in the commercial manufacture of vinegar from waste fruits before alcoholic fermentation is complete, where unsound material is used and pure yeast is not added. "Stuck" tanks, those in which alcoholic fermentation has ceased before fermentation is complete, are common on this account.

Vinegar bacteria themselves are not necessarily injurious to the growth of yeast; it is only the product of their activity, viz., acetic acid, that is harmful.

Effect of Vinegar Bacteria on Sugar. Vinegar manufacturers have stated to the author that sugar remaining in "stuck" fruit juices will be converted by vinegar bacteria into acetic acid without the intervening

step of alcoholic fermentation, but experiments have proved that such is not the case.

Wild Yeasts. Various forms of wild yeast are very troublesome in the fermentation of fruit juices. Most of these have been described in Chapter 11, but brief reference may be made at this time to their relation to vinegar manufacture.

Hansenia apiculata. This wild yeast is present in practically every spontaneous fermentation of fruit juice. It develops very rapidly in the juice and consumes a large proportion of the nonsaccharine yeast foods, reducing these substances to such a degree that the true yeast which develops later finds it very difficult to multiply. It is also thought that *H. apiculata* excretes substances that are poisonous to the true yeasts. For example, it forms acetic acid, which is deleterious to true yeast activity. It forms very small amounts of alcohol and is very inefficient in its alcoholic fermentation; i.e., only a small proportion of the sugar destroyed by this yeast is converted into alcohol. In samples examined by the author, the apiculatus yeast outnumbered the true yeast in fresh apple juice, and in many samples the ratio was 1 million of apiculatus cells per cubic centimeter to 100 or less of the true yeast *Saccharomyces ellipsoideus.* It may be controlled in the fermentation of fruit juices by the addition of a large starter of pure yeast in the manner to be described later.

Mycoderma. Another wild yeast of common occurrence and one which is very objectionable in the preparation of fruit vinegar is Mycoderma, commonly known as "wine flowers." There are, however, other film yeasts, such as Hansenula and Debaromyces, both true, spore-forming film yeasts, which are often confused with this organism and which act in similar manner on alcoholic liquids. It is strongly aerobic and develops on the surface of fermented or fermenting fruit juices or other fermented liquids of alcoholic or sugary nature. It is characterized by its vigorous oxidation of alcohol, sugars, and organic acids to carbon dioxide and water. Where the organism is grown in pure culture in fermented fruit juice it will, in a few months' time, destroy all the alcohol and will convert such a liquid from an acid to an alkaline reaction. Typical oxidizing reactions caused by this organism are the following:

$$6O_2 + C_6H_{12}O_6 = 6CO_2 + 6H_2O$$
$$C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$$

The organism is very common in cider-vinegar factories and develops frequently in the spontaneous fermentation of cider. Normally it develops after the yeast fermentation is complete and before the acetic acid fermentation begins, as a chalky-white, wrinkled film that usually possesses

more or less of a fruity ester odor. Its development in fermented liquids can be prevented by the addition of vinegar or by excluding air. If the acetic acid is increased to 1 per cent or more, Mycoderma does not develop rapidly.

Torula. A third group of wild yeasts of considerable importance in the fermentation of fruit juices is that of the Torula yeasts, which are characterized by rapid growth as sediment yeasts, by low alcohol-forming power, and usually by their spherical appearance under the microscope. They are objectionable in the fermentation of fruit juice for the same reasons as those given for apiculatus yeast. Their growth may be checked by the addition of a pure yeast culture.

Other Wild Yeasts. A number of other yeasts develop in the fermentation of fruit juices, but these need not be described in detail at this time. A discussion of most of these organisms will be found in Chapter 11 and in books on yeasts (see references at end of this chapter).

Desirable Yeasts. In general it may be stated that the most desirable fermentation of fruit juices and other liquids intended for vinegar manufacture is the one carried out by the so-called "culture" yeasts, such as *Saccharomyces ellipsoideus*, *S. malei*, and *S. cerevisiae*, from grapes, apples, and cereals, respectively. These yeasts are characterized by their efficient conversion of sugar to alcohol, by rapid settling after fermentation, and by the production of fermented liquids of clean flavor and normal appearance.

As stated above, the desirable types of yeast are greatly outnumbered by various wild yeasts. In order that the injurious effect of these undesirable organisms may be minimized and that a desirable type of fermentation may be obtained, selected cultures of pure yeasts should be added. This addition will reverse the ratio of wild yeasts to true yeasts and will promote the type of fermentation desired. *Saccharomyces ellipsoideus*, most commonly found in grape-juice fermentations, has been found most satisfactory for fermentation of fruit juices for vinegar manufacture, because of its rapidity of growth and fermentation and its high alcohol-forming power.

For the fermentation of mashes made from starchy materials the yeasts of the *S. cerevisiae* group are best.

Commercial Yeast Culture. Several institutions in the United States distribute cultures of yeasts for vinegar manufacture. Addresses of these may be had from the University of California, College of Agriculture, Davis or Berkeley. The yeast is ordinarily sent to the vinegar manufacturer as a pure culture on nutrient agar-agar in a flask or tube plugged with cotton and with full directions for its increase to sufficient volume for factory use.

The following yeasts in common use in California wineries are satis-

factory for the fermentation of fruit juices: Champagne Ay, Burgundy, and Tokay. All are strains of *Saccharomyces ellipsoideus*.

Preparing a Yeast Starter. As stated in the preceding paragraph, the yeast will usually be purchased as a pure culture growing on nutrient agar in a flask or tube plugged with sterile cotton. The first step in its propagation at the vinegar factory consists in adding to the flask or tube from a freshly opened bottle of apple juice or grape juice, from a grocery store, sufficient juice to half fill the flask or tube. Follow the usual precautions to avoid infection of the juice with mold or other spoilage organisms.

Set the culture aside in a warm room at about 65 to 75°F. (not above 80°F.) for several days until in full fermentation (vigorous evolution of gas). Then open a gallon bottle of commercial apple juice or grape juice; pour off about one-fourth of the contents, and to the remaining three fourths in the gallon bottle add the entire contents of the fermenting juice of the pure culture. Mix well and insert in the neck of the gallon bottle a loose plug of sterile absorbent cotton. Set aside until in full fermentation, usually 2 to 3 days.

In the interim sterilize about 40 to 45 gal. of fresh juice made from clean, sound apples or grapes, or other fruit, by heating the juice to 160 to 165°F. in a flash pasteurizer, or by inserting a steam hose into a 50-gal. barrel containing about 40 gal. of juice. Use a thermometer. Let the juice cool in a 50-gal. barrel to room temperature, with bung closed with a loose plug of sterile cotton. The juice must be cooled to not above 75°F. before use. Cooling overnight should be, but may not be, sufficient; use a thermometer.

Next shake and add the contents of the rapidly fermenting gallon bottle of juice. Mix well. Let stand until in full fermentation, usually in 2 to 4 days.

Crushing and Pressing. Cull apples, apple cores, and peels are crushed in a hammer mill and pressed in a rack-and-cloth press as previously described for apple juice (Chapter 12). The juice is pumped to a fermentation tank, usually of redwood in California, and of 10,000 to 50,000 gal. capacity. The pomace, press cake, is usually sold for use as part of the ration for dairy cows.

White grapes are crushed and then pressed in a basket press or in a rack-and-cloth press, and the juice fermented free of skins and stems. Red grapes, on the other hand, are crushed and stemmed, then fermented in open vats before pressing, in order to extract the red color from the skins.

Apricots, peaches, plums, prunes, pears, and most other fruits, if used for making vinegar, should be crushed into open vats, and a pectic enzyme added in order to hydrolyze pectic substances during fermentation of the

FIG. 99. Hydraulic-basket grape presses and hydraulic pump. (*Healdsburg Machine Shop, Healdsburg, Calif.*)

crushed fruit. Unless this is done it will be found almost impossible to press the fermented fruit and the yield of vinegar stock will be very small.

Addition of SO_2. It was found by Cruess, Sifredi, and Zion a number of years ago that the average alcoholic fermentation in commercial-vinegar factories was very inefficient; alcohol yields were low, and fermentation was often incomplete. It was also found that if a small amount of SO_2 or one of its salts was added before fermentation, a much cleaner fermentation, with higher yield of alcohol, was obtained. The experiments were conducted both on a small scale in the laboratory and on a commercial scale in 30,000-gal. lots. Usually an increased yield of 1 per cent or more of alcohol was obtained in comparison with that obtained by uncontrolled fermentation. For example, if the alcohol content of the fermented apple juice made without SO_2 was 6 per cent, that made with SO_2 would be 7 per cent or more.

It was found that the addition of about 125 p.p.m. of SO_2 or an equivalent amount of bisulfite or metabisulfite was sufficient. It almost completely inhibited the growth and activity of molds, wild yeasts, vinegar bacteria, and lactic bacteria but permitted rapid growth of and fermentation by the desirable true yeast *Saccharomyces ellipsoideus*.

If sulfur dioxide gas is used, it is purchased in the form of the liquefied product in large steel cylinders. A cylinder of the liquid SO_2 may be placed

on a scale and the outlet valve connected by hose to a stainless-steel or hard-rubber or plastic tubing which is inserted in the tank or vat of juice or crushed fruit. The tubing is in the form of a cross and should have a considerable number of small holes along that portion that is submerged, in order to distribute the gas. The amount of gas required is calculated, the cylinder of gas weighed, and then gas is allowed to flow from it to the distributor until the calculated weight of gas has been taken from the cylinder. Or an aqueous solution of SO_2 of known strength can be made up by bubbling the gas into ice water, and the required volume of this solution added to the juice or crushed fruit. If sulfite or bisulfite is used, it can be dissolved in water to give a solution of known concentration, such as 1 lb. per gal., and the required volume added to the material to be fermented. The contents of the tank or vat must, of course, be thoroughly mixed with the SO_2 or bisulfite by pumping over or other means. An addition of 4 oz. of SO_2 or 7½ oz. of bisulfite or metabisulfite per ton of crushed fruit or 200 gal. of juice will usually be about the proper quantity.

After addition of the SO_2 or bisulfite the juice or crushed fruit should be allowed to stand about 2 hr. before adding a starter of yeast; this permits the SO_2 to kill or paralyze molds, wild yeasts, and bacteria and much of the free SO_2 to combine with sugars and other components of the fruit.

Using the Starter. Fifty gal. of actively fermenting liquid will be enough to inoculate five hundred gal. of fresh juice containing about 125 p.p.m. of SO_2. The 50 gal. of starter is previously prepared as directed earlier in this chapter. This amount of juice should be pressed from sound, selected, and well-washed fruit, and the juice should be placed in a clean tank, preferably one that has been washed thoroughly with a sal soda solution and steamed to render it as nearly sterile as possible. It is then mixed with the 50 gal. of starter. Within 4 or 5 days the 500 gal. of juice will be actively fermenting and can be used to inoculate about 5,000 gal. of fresh juice. The 5,000-gal. tank of juice can, in turn, be used to inoculate 50,000 gal. of juice. From this point the fermentations in the factory may be started by using 10 per cent by volume of actively fermenting juice from a tank previously inoculated by pure yeast starter.

In factories where fruit of an inferior quality is used, i.e., fruit which is often fermenting or vinegar-soured when received, it will be necessary to renew the pure yeast culture frequently during the season; but if fruit of sound quality is used, one culture will be sufficient for the normal vinegar-making season.

Aeration. The growth of culture yeasts is increased by aeration and agitation of the fermenting liquid. Aeration mixes the yeast thoroughly with the fermenting liquid. It removes carbon dioxide, which has a retarding influence on fermentation, and furnishes oxygen, which favors the growth of the yeast. In the ordinary vinegar factory, however, sufficient

aeration is obtained by the crushing, pressing, and pumping of the liquid before fermentation. It has been found advisable to aerate by pumping over tanks of juice that have become sluggish in fermentation and in which there is danger of "sticking," i.e., complete ceasing of fermentation.

Temperature Control. During the fermentation of any liquid in large tanks the temperature rises because of the heat liberated during the conversion of sugar into alcohol. The alcoholic fermentation of 1 gram of sugar liberates 120 cal., and the fermentation of 1 gram of sugar per 100 cc. of juice would theoretically increase the temperature 1.2°C., or approximately 2.16°F. Yeast fermentation ceases at 95 to 105°F., or approximately 35 to 40.5°C. Grape juice normally contains about 22 per cent sugar, and in the fermentation of this amount of sugar the rise in temperature would be approximately 47.5°F., if no heat were lost by radiation. It has been found in commercial practice, where fermentation vats of 2,000 gal. or greater capacity are used and a normal summer temperature of 85 to 95°F. during the day prevails, that it will be necessary to cool the fermenting liquid artificially. The usual means of accomplishing cooling of fermenting fruit juices is to pump the liquid through pipes surrounded by jackets of circulating cool water. In some cases metal coils, through which cool water is circulated, are immersed in the fermenting juice.

Artificial cooling of the liquid is seldom necessary in the fermentation of apple juice, because of its low sugar content and because apples are usually crushed during the fall months when the temperature is not sufficiently high to cause sticking of fermentation.

High temperatures are not only injurious to yeast fermentation but also are objectionable because they favor the growth of lactic acid and vinegar bacteria. If possible, the temperature of the fermenting liquid or pulp should be maintained between 75 and 85°F. The optimum temperature for most varieties of culture yeasts used in the fermentation of fruit juices is about 80°F.

Sanitation. The fermentation tanks should be thoroughly cleansed before being filled with fruit juice or other liquid intended for vinegar manufacture. Besides being well washed, the tank should be treated with a solution such as hot sal soda, or sulfur should be burned in the tank to destroy mold spores, vinegar bacteria, and other objectionable microorganisms. Sour press cloths, unclean crushers, pumps, etc., are prolific sources of contamination of fruit juices with undesirable types of organisms. Such equipment should be kept clean and should be thoroughly washed at the end of each day's operations.

Increasing the Temperature. The alcoholic fermentation occurs in two stages, one known as the "preliminary," or "violent," fermentation, during which most of the sugar is converted into alcohol and carbon dioxide, and fermentation is so rapid that foreign organisms find it difficult

to develop. The secondary fermentation is very much slower than the preliminary fermentation and usually extends over a period of 2 or 3 weeks as compared with a period of 3 to 6 days for the preliminary period.

During the secondary fermentation there is danger of contamination by vinegar bacteria, "wine flowers," and lactic acid bacteria. Should the secondary fermentation become very sluggish, it may be necessary to aerate the liquid and thus invigorate the yeast. During the cold winter or late fall months it may be necessary to heat the fermentation room artificially in order that fermentation may not be arrested by low temperatures.

Balling Readings. The progress of fermentation is readily observed by determining the Balling degree of samples of the fermenting liquid taken daily. When fermentation is complete, the Balling hydrometer usually registers 0° or less.

Fermenting and Pressing Crushed Fruits. Crushed red grapes, pears, peaches, apricots, or other pulpy fruits are allowed to ferment in open vats, for the purpose of extracting the red color from the grapes and for rendering other fruits more easily pressed. During fermentation the crushed mass is stirred occasionally, usually by drawing off some of the free-run juice and pumping it over the surface of the fruit in the vat. If the vat is small, 3,000 gal. or less, the mass can be stirred by means of a pole, on the end of which is a circular piece of 2-in. redwood or pine about 12 in. in diameter.

After 4 to 5 days of fermentation, the free-run wine or fermented juice is drawn off and the drained solids pressed in a basket-type grape press or rack-and-cloth press. The two liquids are combined and pumped to a storage tank for completion of fermentation. As previously suggested, the addition of pectic enzyme to the crushed fruit before fermentation greatly facilitates pressing after fermentation. The enzymes may be had from producers, such as Rohm and Haas Company, Philadelphia, or the Takamine Laboratories, New York, with full directions for use.

The Vinegar Bacteria. Vinegar bacteria are members of the genus *Acetobacter* and characterized by their ability to convert ethyl alcohol, C_2H_5OH, into acetic acid, CH_3CO_2H, by oxidation. This genus includes several species, such as *Acetobacter aceti*, *A. xylinum*, *A. kützingianum*, *A. pasteurianum*, and others. Two species, *A. schüzenbachii* and *A. curvum*, form curved cells. Usually the bacteria as seen under the high power of the microscope are in the form of very small, very short rods, which in some cases may be mistaken for cocci. They appear as single cells, pairs, and as chains of cells.

Some species form a tough, glossy semitransparent mass of variable thickness on hard cider or other fermented fruit juice. *A. xylinum* is especially noted for this property. On the other hand, some species do not form such a growth but are found throughout the fermented juice.

While most vinegar bacteria appear as very short rods under the micro-

scope, Vaughn (1942) states that involution forms are not uncommon. These include spherical, elongated, filamentous, club-shaped, curved, and even branched cells. Young cells are Gram-negative, i.e., do not stain with the Gram stain. The genus is strictly aerobic and has the ability to oxidize not only ethyl alcohol but a considerable number of other organic compounds. Vaughn states that *Acetobacter* is unable to convert appreciable amounts of dextrose directly into acetic acid. Motility of the cells is sometimes observed under certain conditions but is not common. When it does occur, a polar flagellum can be demonstrated. *Acetobacter* does not form spores.

Vaughn (1942) has given detailed instructions for bacteriological differentiation of the various species of *Acetobacter*. He states that this genus has been encumbered with a large number of species, and it is probable that in a considerable number of cases a single species has been given several names. For example, the key to classification of the genus does not recognize such species as *A. pasteurianum*, *A. kützingianum*, *A. zeidleri*, *A. acetosum*, *A. ascendens*, and several others, since most of these are probably varieties of *A. aceti*, *A. xylinum*, or *A. rancens*. See also "Bergey's Manual of Determinative Bacteriology" for complete descriptions of most of the recognized species of *Acetobacter*.

Settling and Racking. Following the secondary fermentation, the yeast and fruit pulp settle rapidly to form a compact sediment in the fermentation tank. In most factories the fermentation vats are used for the storage of the liquid during the first 10 days or 2 weeks of fermentation only, and the final stages of fermentation are normally completed in large storage tanks often containing from 30,000 to 50,000 gal. each. In the normal fermentation the sugar content in the fruit juice or other liquid is reduced to less than 0.5 per cent sugar in a period of 3 or 4 weeks after the time of crushing. If more sugar than this is present at the end of 4 weeks, it is an indication that fermentation has been imperfect for one or more reasons. It is possible that the temperature has been too high or too low, that bacterial fermentation has retarded yeast fermentation, or that the liquid contained too much sugar before fermentation. Few yeasts will completely ferment juices of more than 30° Balling.

After the fermentation is completed and the yeast has settled, the fermented liquid should be separated from the yeast sediment as completely as possible, since the sediment tends to undergo decomposition, resulting in the formation of undesirable flavors or the development of lactic bacteria, which seriously interfere with acetic fermentation.

The process of the separation of the liquid from the sediment is known as "racking" and is accomplished by drawing off the liquid by gravity through a faucet, by siphoning, or by pumping. The residual sediment is rich in yeast and contains a large amount of liquid suitable for vinegar

making, which can be recovered by filtering the sediment through filter bags or filter presses, but in most factories the sediment is discarded.

Storage of the Fermented Fruit Juice. Many vinegar factories store the fermented juices in tanks that are more or less exposed to the atmosphere. This is a mistake, for the reason that it permits the growth of Mycoderma, or "wine flowers," with a resulting loss of alcohol and injury to the quality of the product. If the juice is to be held for several months, one of two things should be done: the fermented juice should be stored in well-filled closed tanks to exclude air and thereby prevent growth of Mycoderma, or it should be acidified by the addition of vinegar to increase the acidity of the liquid to at least 1 per cent acetic acid.

Joslyn (1955) states that acidification to 1 per cent or more of acetic acid will enable the producer to avoid the internal-revenue wine tax. It has been reported by several vinegar manufacturers that 1 per cent acetic acid does not always prevent the growth of "wine flowers" (Mycoderma) and therefore they often acidify to 2 per cent acetic acid content. Crawford states that the loss from uncovered fermented cider in 6 to 12 months may amount to 25 to 50 per cent of the alcohol.

Alcohol Content. The fermented liquid must not be so high in alcohol content that vinegar bacteria cannot function. Wine should be diluted to about 10 per cent alcohol content. Other fermented fruit juices usually do not require dilution.

Slow Methods of Acetification. There are two general methods in use for the conversion of alcoholic liquids to vinegar. One of these is the slow process, of which there are several modifications, and the second method is the generator, or quick, process. The various modifications of the slow process and the generator process will be discussed separately.

"Let-alone" Slow Process. In the manufacture of vinegar in the household or in the orchard, the juice is usually allowed to undergo spontaneous fermentation in barrels, and the barrels are left partially filled with the bung open until the product changes to vinegar of its own accord. The alcoholic fermentation is often incomplete and imperfect. Usually the liquid becomes covered with wine flowers, and in most cases acetic acid fermentation is very slow. An abundant supply of air is necessary for the satisfactory acetification of any liquid. This fact is often not realized by the amateur vinegar maker, and it is not uncommon to observe completely filled, tightly sealed barrels or other containers set aside to become vinegar, a condition which of course prevents acetification. The "let-alone" process is very unsatisfactory, is very slow, and often results in the production of a very inferior product.

The "Orleans" Process. In this process, which is much more desirable, the fermented liquid is placed in barrels which are filled about three-quarters full, holes are bored at both ends of the barrel a few inches above

the surface of the liquid, and the bunghole in the barrel is left open. The holes should be covered with fine screen or with cheesecloth to exclude vinegar flies. To the fermented liquid is added from one-fourth to one-fifth of its volume of fresh vinegar. This acidifies the liquid to the point where the growth of Mycoderma is prevented and the growth of vinegar bacteria is promoted. It also impregnates the liquid with a very large number of active vinegar bacteria and is in the nature of a starter of vinegar bacteria. A temperature of 70 to 85°F. should be maintained. Usually at the end of 3 months the liquid will be converted into vinegar. One-fourth to one-third of the vinegar may then be drawn off for bottling purposes and an equivalent volume of alcoholic liquid added. From this point forward one-third to one-fourth of the volume may be drawn off at monthly intervals and an equivalent amount of alcoholic liquid added. This process results in aging of the vinegar during acetification and produces a vinegar superior in flavor and general quality to that of either the "let-alone" process or the generator process. It is used extensively in Europe in the preparation of vinegar from wine.

Pasteur Process. Pasteur discovered that vinegar bacteria tended to develop on the surface of the liquid with the formation of a translucent film which he believed to be the principal agent in acetification. He also noted that in the usual Orleans process this film was disturbed during the drawing off of the vinegar and the addition of the new wine or cider and that the tendency of the film was to settle to the bottom of the barrel where in time the accumulation became so great that it interfered with normal acetification. The submerged film tends to destroy acetic acid. He therefore modified the Orleans process by placing on the surface of the liquid a grating made of thin strips of wood, which retained the film at the surface. By using a shallow tank and thereby increasing the ratio of the surface exposed to the volume of liquid in the tank, he obtained very rapid acetification. The liquid is acetified initially with one-fourth to one-fifth its volume of new vinegar, as described above for the Orleans process.

Observations made by the author in 1915 indicate, however, that the growth of the film is not a necessary condition. In fact, the most rapid acetification of wine and cider was obtained by the use of cultures that did not form such a film. It is possible that the growth of a heavy leathery film on the surface of the liquid tends to exclude air and actually reduces the rate of acetification.

The Generator, or Quick, Process. The rate of acetification is proportional to the amount of oxygen in contact with the reacting components or, in other words, to the surface exposed to the air, since oxygen of the air is one of the two reacting substances. If the surface, therefore, is increased, the rate of acetification is proportionately increased. This

principle is made use of in the quick process, otherwise known as the "generator process," or German process.

Old-style Upright Generators. While the old-style upright generator described in this section is obsolete and seldom used in modern plants, the following description and discussion illustrate the principles of the quick process and on that account are retained in this chapter. In this method a tank, usually cylindrical and upright in form, is filled with a substance that will permit the vinegar to percolate freely and upon which vinegar bacteria may develop. The substance most commonly used is beechwood shavings, since they retain their tightly coiled condition even when wet with vinegar and therefore do not pack tightly in the generator. Corncobs and rattan shavings are also used successfully in generators for the manufacture of fruit vinegar. The rattan shavings are tied to poles to form upright bundles, which are packed tightly in the generator. If not used in this manner, rattan shavings tend to settle into a compact inactive mass. In the manufacture of distilled vinegar, charcoal and coke have been used, although the beechwood shavings are preferred. Coke is more durable than charcoal and is the usual filling material in cider-vinegar generators in California.

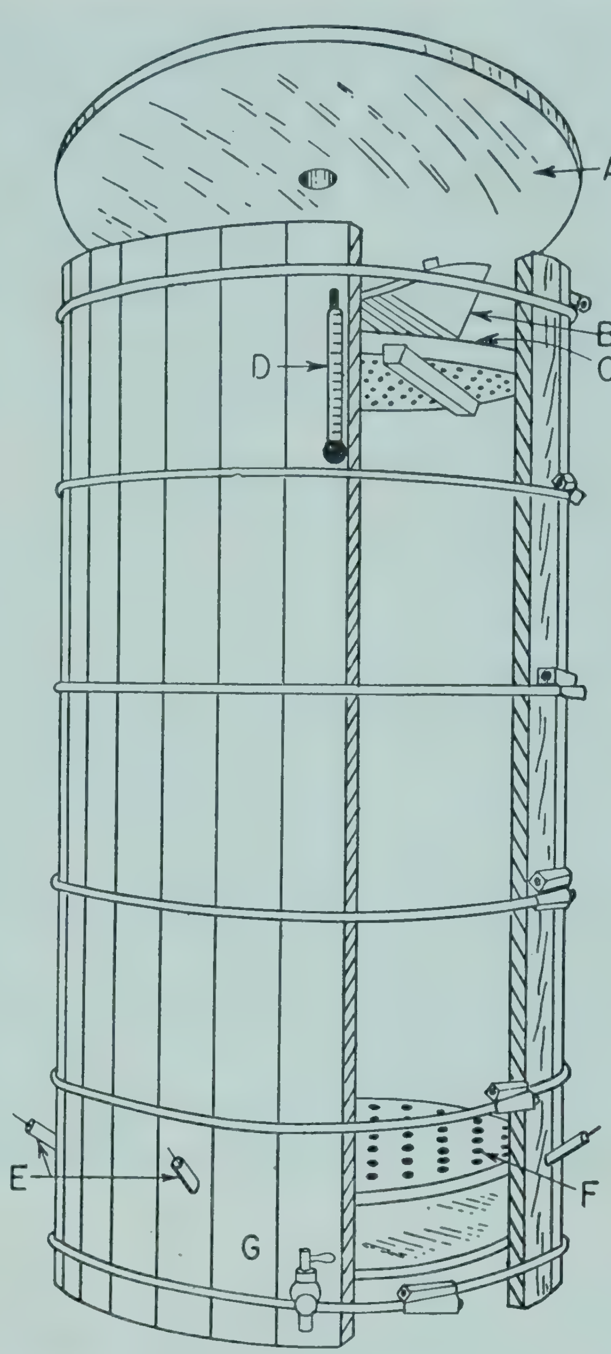


FIG. 100. Old-style, upright vinegar generator. *A*, cover; *B*, distributing trough; *C*, distributing head; *D*, thermometer; *E*, air inlets; *F*, false bottom. (*Hydraulic Press Mfg. Co.*)

The old-style generator, formerly in common use, is about 48 to 60 in. in diameter and from 10 to 14 ft. in height and contains three compartments. However, generators of this type, 8 to 10 ft. in diameter, are also in use. A central compartment occupies most of the generator and contains the shavings or other generator material. It is equipped with adjustable openings near the bottom of the generator for admission of air. Angle-stem, or recording, thermometers are inserted near the center of the compartment.

Above this compartment is a distributing compartment in which is located a tilting W-shaped trough into which the fermented liquid flows in a small stream. The axis of the trough is so placed that when one side has

filled with the liquid, it tilts and brings the other side of the trough under the stream, which in turn fills and tilts. This tilting action distributes the liquid over the bottom of this compartment, which is perforated with small holes through which the liquid flows to the generating compartment below. It trickles slowly over the shavings or other filling material and is oxidized to vinegar during passage. In very large generators the liquid is distributed by revolving perforated stainless-steel or hard-rubber pipes acting on the principle of the familiar revolving sprinkler used to water lawns. The third compartment is merely a receiving chamber for the acetified liquid. The construction of such a generator is shown in Figure 100.

Use of Upright Generator. In order to start the generator, it is first necessary to acidify the shavings or other filling material, which may be done by filling the generator with new cider vinegar or other fruit vinegar. This vinegar will not only acetify the filling material but will also impregnate it with active vinegar bacteria. Following acidification of the shavings, a fermented liquid acidified with vinegar should be slowly passed through the generator in order to stimulate growth of the vinegar bacteria. Within a few days the growth of the bacteria will have proceeded sufficiently to permit normal operation of the generator.

In the "one-run process" the alcoholic liquid is acidified by the addition of vinegar to increase the acidity to 3 to 3½ per cent, representing about 1 gal. of hard cider to 2 gal. of vinegar. One passage of this liquid through the generator will convert the remaining alcohol to acetic acid. In the case of cider this will mean an increase of acidity from 3 or 3½ per cent to about 6 per cent.

In the "two-run process" the blend of vinegar and fermented juice is passed through the generator to become partially acetified, and this liquid is then passed through a second generator to complete the process. The operation of the generator must be carefully controlled by frequent determinations of alcohol and acid of the ingoing and outgoing liquids.

Revolving Generators. In commercial installations using this principle, a large cylinder filled with shavings revolves within a tightly constructed wooden housing. The lower half or less of the cylinder is immersed in the liquid to be acetified, while the upper section is exposed to the air. The exposed surface remains wet owing to rotation of the cylinder. Air is admitted to the compartment through adjustable openings. The generator revolves very slowly, at the rate of about 1½ revolutions per hour in the plant observed by the writer. The generators in question in this particular case held approximately 500 gal. each of fermented cider, and approximately 3 weeks was required for complete conversion to vinegar. The revolving generator has not proved so popular as the upright type.

Recirculating Generators. In most California cider-vinegar factories recirculating generators are used. These are wooden tanks of wide diameter

(15 ft. or more) usually filled with pieces of coke about 3 to 5 in. in length and 1½ to 2 in. in diameter. Beechwood shavings have also been used, but are more expensive than coke and more apt to break during periodic emptying of the generator and washing of the filling material. The bottom compartment is several feet in depth and holds 5,000 gal. or more of vinegar stock. A pump connected to this compartment circulates the vinegar stock through a perforated stainless-steel or hard-rubber revolving, cross-shaped distributing arm in the topmost compartment and distributes the stock evenly and continuously over the coke or other filling material. A tubular, water-jacketed heat exchanger outside the generator maintains a safe temperature in the generator, as the stock is pumped through it on its way to the distributing arm. Usually the temperature is held between 80 and 90°F., although in one large plant the range is 90 to 100°F. and is reported to give good results (Figure 101).

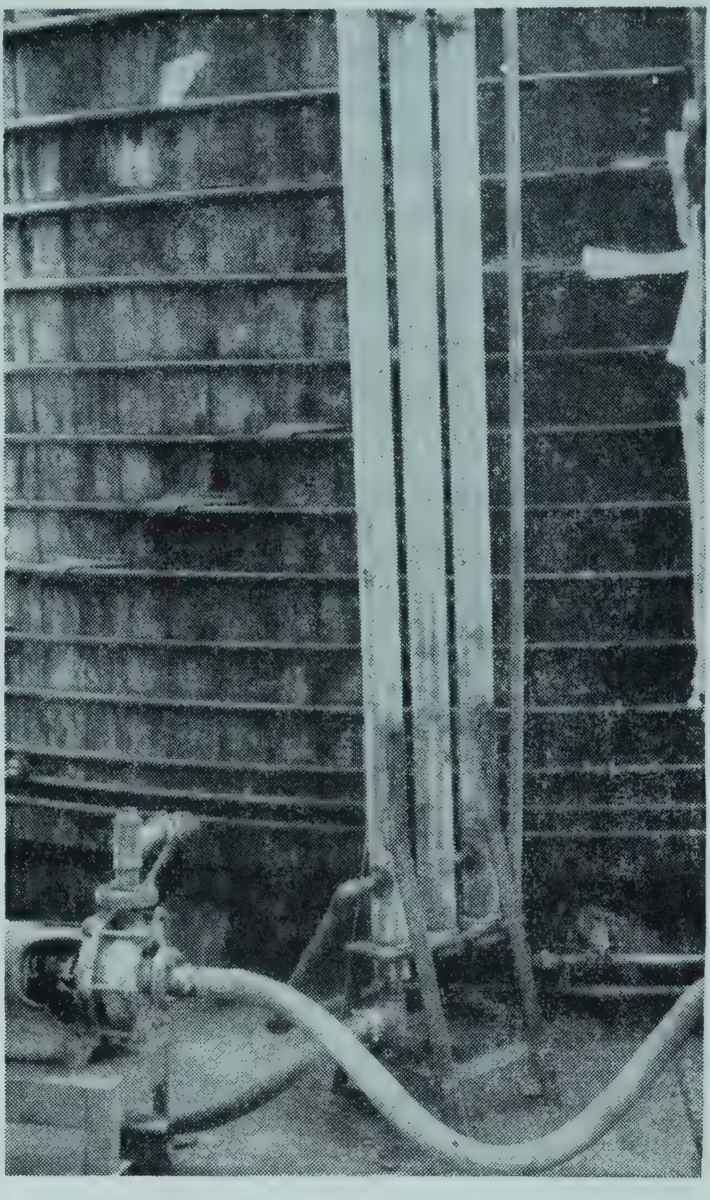


FIG. 101. Recirculating vinegar generator showing recirculating pump and vertical, stainless-steel cooling tubes. Tubes jacketed and cooled with cold water.

In some generators air is admitted through adjustable intakes near the lowermost compartment; in others a small fan supplies air under slight pressure above the level of the liquid in the bottom compartment and beneath the false bottom that supports the coke or other filling material.

Samples are taken frequently for determination of acidity and alcohol content. Usually acetification is complete within a week or less. The final total acidity is usually above 60 grains, i.e., above 6 per cent expressed as acetic acid, when fermented apple juice is the raw material.

While coke is an efficient filling material for vinegar generators, it usually contains considerable iron as the oxide or in other form that is soluble in vinegar. If present in sufficient amount in the vinegar, clouding and darkening are apt to occur, making it necessary to use ferrocyanide or other rather drastic treatment to remove the Fe compounds. However, after extended use the iron content of the coke becomes so low as to no longer be a serious hazard.

When acetification is completed, about two-thirds of the vinegar is drawn off and the remainder is left to acidify and inoculate the next lot of vinegar stock.

"Mother of vinegar" eventually forms in such quantities on the shavings, coke, or other filling in the generator that it becomes necessary to cease operation, remove the filling, and thoroughly scrub and wash it. After refilling the generator the washed shavings or coke must be saturated with strong vinegar and the generator again built up to full operation. However, this difficulty (sliming, or "plugging up") is encountered also with the old style of generator previously described and is not peculiar to recirculating generators. Wine as well as hard cider when used as stock causes sliming of the filling material; but little difficulty is encountered when dilute ethyl alcohol is the raw material. It is used in making distilled vinegar.

Submerged Acetification. Joslyn (1955) states that Hromatka has reported on a new method of making vinegar in which the vinegar stock is placed in a stainless-steel tank, and air in the form of very small bubbles is continuously passed through the stock. A Jena glass 6–4 sinter plate can be used as an aerator for this purpose. The vinegar bacteria must be in contact with air at all times since it is reported that they will die if deprived of it for more than 15 sec. Although stainless steel is recommended for construction of the tank, it is probable that some other less costly material such as redwood could be employed.

The vinegar bacteria suspended in the liquid combine oxygen supplied by the air stream with the alcohol of the vinegar stock to form acetic acid; it is likely that they utilize the oxygen that has dissolved in the liquid. The acetification is very efficient; yields of up to 98 per cent of the theoretical are obtained. If the oxygen content of the bubbles is increased to 60 per cent of the supplied gas mixture, the bacteria are harmed; air naturally contains about 20 per cent of oxygen.

Since there is no solid filling in the submerged fermentation "generator," such as coke or shavings, sliming is eliminated and there is no pickup of iron or copper, such as occurs with coke filling. Joslyn states that two commercial vinegar producers are using the submerged acetification method in California and that another has installed an experimental pilot-scale unit. He states also that the latest Frings generators are of this type, whereas the earlier generators were similar in some respects to the recirculating type described earlier in this chapter. It has been predicted that the submerged acetification method will greatly increase in importance, since it has so many advantages over the conventional generators now in use.

Control of Temperature during Acetification. In the slow, or Orleans, process the barrels of vinegar should be kept in a warm room so that the

temperature in the container will be favorable for the activity of vinegar bacteria. The optimum temperature for their growth is about 85°F. In the generator process, because of the great rapidity of the oxidizing reaction, the temperature tends to rise on account of the heat liberated. One gram molecule of alcohol during its conversion to acetic acid will liberate 115 Cal. of heat, which is several times the amount of heat liberated during the fermentation of 1 gram molecule of sugar to alcohol, in which case 22 Cal. of heat is liberated. This corresponds to 2.5 Cal., or 2,500 cal. per gram of alcohol, converted to acetic acid; or enough heat is liberated by the oxidation of 1 gram of alcohol to acetic acid to raise the temperature of 100 cc. of water 25°C. (45°F.), if no heat were lost by radiation. Usually, therefore, in the generator process the problem is one of maintaining the temperature below the danger point of 40°C. (105°F.), the temperature at which acetic acid bacteria are reported to be inactivated.

Temperature is usually controlled in a vinegar generator, except in the very large recirculating type, by two means: by adjustment of air intake and by rate of flow of liquid. If the temperature has become too low, it may be increased by increasing the flow of liquid and by admitting a larger volume of air through the air intakes at the bottom of the generator. This will result in the oxidation of a larger amount of alcohol per unit of time and in an increase of temperature. On the other hand, if the temperature rises above the optimum of 85°F., the rate of flow of the liquid must be decreased and the air intake reduced. During the warm summer months the temperature of the generators must be carefully regulated to prevent excessively high temperatures.

As previously mentioned, when very large generators of the circulating type are employed it becomes necessary to use a water-cooled heat exchanger on each generator in order to maintain a safe range of operating temperature (Figure 101).

Losses during Acetification. In the operation of generators appreciable amounts of alcohol and acetic acid are lost by evaporation, by oxidation to carbon dioxide and water, and by being utilized by the vinegar bacteria for their growth. Small amounts of alcohol also remain unconverted in the finished product. Theoretically 1 gram of alcohol should yield 1.304 grams of acetic acid. In practice 1 cc. (0.7938 gram) of alcohol normally yields about 1 gram of acetic acid instead of the theoretical 1.035 grams, and 1 gram of alcohol yields only 1.26 grams of acetic acid. In improperly regulated generators, where the supply of air passing through the generator is too great, the yield may be much less than this. In extreme cases it is possible for all the alcohol entering the generator to be converted into carbon dioxide and water with the formation of practically no acetic acid. The reaction involved in this case is $C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$. It

is very essential, therefore, that the proper balance between air intake and flow of alcoholic liquid be maintained. In the submerged acetification process such losses are almost completely eliminated.

Aging of Vinegar. Freshly made vinegar, especially that prepared by the generator process, is somewhat harsh in flavor and odor. It has been claimed that this flavor is due to the presence of higher alcohols, acetaldehyde, and acids. If new vinegar is placed in well-filled tanks or barrels and allowed to stand for 6 months or a year, the harsh flavor disappears and is replaced by a mild, agreeable flavor and pleasing "bouquet" or odor. The changes that occur during this period are probably similar to those that occur in the aging of wine. The combination of ethyl alcohol and acetic acid, according to the following reaction, to form ethyl acetate, is an example of the reactions that probably occur during aging.

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH} + \underset{\text{acetic acid}}{CH_3CO_2H} = \underset{\text{ethyl acetate}}{CH_3CO_2C_2H_5} + \underset{\text{water}}{H_2O}$$

In the slow process of vinegar manufacture, aging and acetification occur simultaneously, and therefore such vinegar is ready for use when acetification is complete. Vinegars from generators, on the other hand, should not be used until they have been aged for at least 6 months. Aging should take place in well-filled wooden containers, as it has been found that it does not occur satisfactorily in glass. Aging takes place more rapidly and satisfactorily in small cooperage than in very large tanks.

Fining of Vinegar. Vinegar to be attractive should be brilliantly clear, which condition may be accomplished by either filtration or fining.

Common fining materials are "isinglass," casein, gelatin, and high-grade bentonite clay. The finely ground bentonite clay is soaked several days in water or vinegar and is then broken up into a fine suspension by vigorous agitation to give a "solution" containing 5 per cent of the clay. This can be done easily by arranging a barrel on a shaft so that it may be rotated. Water and powdered clay may be rapidly converted to a smooth "solution" by high-speed mechanical stirring in an open barrel. To clarify the vinegar, about 1½ gal. of the 5 per cent suspension is mixed thoroughly with each 100 gal. of vinegar, and the mixture is allowed to settle. After settling, the clear liquid is racked.

It is desirable to make a preliminary clarifying test with small bottles of vinegar with a standard 5 per cent suspension of the clay in order to determine the amount necessary for the larger amount of vinegar.

"Isinglass," fish glue dissolved by soaking in water acidified with citric acid equal in weight to the amount of isinglass used, is also a good clarifying agent. An ounce of isinglass may be dissolved in ½ gal. of water by soaking for 24 hr. in the acidified water and by rubbing the soaked isinglass through a fine screen. To clarify the vinegar the solution is added to 50-gal. barrels

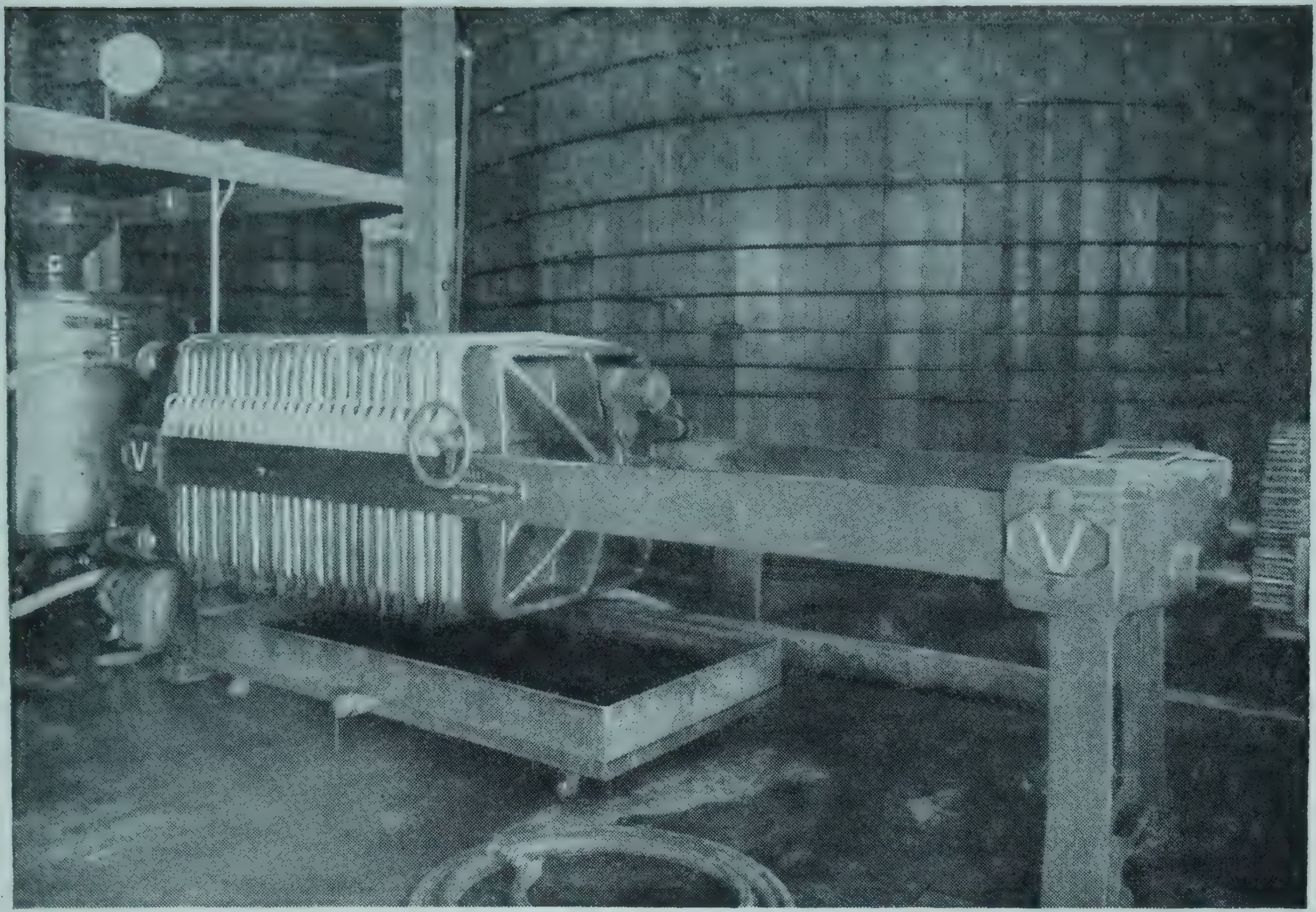


Fig. 102. Filter press for filtration of juice, vinegars, and wines. (*Valley Foundry Co., Fresno, Calif.*)

and thoroughly mixed by stirring. The barrels are closed, the liquid is allowed to settle for a week or 10 days, and the clarified vinegar is separated from the sediment by siphoning.

Casein is also an excellent clarifying agent. It is purchased as "water-soluble" casein, which is a caseinate of K or Na, readily soluble in hot water. A 2 per cent solution is prepared by heating in water. The usual dosage is 1 gal. of this solution per 100 gal. of vinegar.

Vinegar may also be clarified with tannin and gelatin. The tannin is dissolved first in the vinegar and mixed thoroughly with it. The gelatin is dissolved in water by heating approximately 4 oz. of gelatin in each gallon of water. Approximately equal proportions of the tannin and gelatin are used. The usual dosage is 2 to 4 oz. of each per 100 gal.

Filtration. The usual method of clearing vinegar is that of filtration. A very satisfactory filter is a filter press consisting of plates and frames of stainless-steel, hard-rubber, or corrosion-resistant aluminum bronze. A small amount of infusorial-earth filter aid, such as Hy-Flo Super Cel or Dicalite, is added to the vinegar before passing it through the filter press. The filter aid builds up a filtering layer on the cloths of the filter press.

A pulp filter such as described in Chapter 12 also may be used. However, it should be constructed of stainless steel or other resistant metal and not of copper or tinned copper, as these metals are corroded by the vinegar and may then cause clouding.

For polishing filtration of vinegar for bottling, any good type of pad filter, such as the Ertel, Seitz, Lomax, and others, may be used. The vinegar must be previously roughly filtered or fined, as a polishing filter of this type will soon become clogged and cease to operate if used with cloudy vinegar.

Metal Haze. White wine vinegar as well as cider vinegar is subject to clouding if it contains an excess of iron dissolved by the juice or vinegar from equipment such as pumps, pipelines, etc. In other words, iron "casse" is likely to develop when ferrous iron from such sources oxidizes to the ferric condition. The ferric ions react with tannin, phosphates, and probably with proteins to form colloidal precipitates that make the vinegar hazy or cloudy.

Tin and copper salts also may cause clouding. These and also iron salts are best removed by treatment with potassium ferrocyanide.

Treatment with ferrocyanide should be undertaken only by a chemist who is thoroughly experienced in its use. If improperly done, a residue of ferrocyanide or of cyanide may remain in the vinegar, a condition that may be dangerous to consumers and which is prohibited by pure food and drug regulations.

Pumps, pipelines, filters, and other equipment which comes in contact with the must or vinegar should be of resistant metal, preferably stainless steel, or of hard rubber or wood. Resistant bronzes are now commonly used for construction of pumps and filters, while hard rubber is generally used for vinegar pipelines and even for pumps.

Pasteurizing Vinegar. After filtration, vinegar sometimes becomes cloudy because of the growth of vinegar bacteria. This may be prevented by heating the filtered or clarified vinegar to 140°F. for a few seconds. The pasteurization of vinegar in bulk is accomplished by heating it in a continuous stream in a steam-jacketed stainless-steel or aluminum pipe or plate-type pasteurizer such as the APV to the pasteurizing temperature and cooling it at once in a water-cooled unit. Bottled vinegar may be pasteurized by immersing the filled bottles in tanks of water and heating the contents of the bottles to 140°F., as described in Chapter 12, or by flash pasteurization accompanied by filling the bottles hot. Close filtration into sterile bottles may also be used as a means of preservation.

Use of Sulfur Dioxide. If bottled vinegar is inclined to become cloudy from the growth of vinegar bacteria, such growth can be prevented by adding about 110 to 150 p.p.m. of sulfur dioxide or an equivalent amount of sodium bisulfite before bottling.

Containers for Vinegar. Vinegar is marketed in barrels and in bottles. Formerly oak barrels were commonly used for bulk vinegar, but at the present time spruce is used extensively, the interior of the barrels being

heavily coated with paraffin. Barrels for shipment of bulk vinegar should, of course, be thoroughly cleansed before use and should be free of any moldy or other disagreeable flavor or odor.

The best grades of vinegar are most profitably marketed in glass containers. Vinegar in bottles should be brilliantly clear, well aged, and of pleasing flavor and odor. The bottles are, at the present time, sealed with the ordinary Crown cap of the type described elsewhere for fruit juices. Screw caps made of plastic and lined with shellacked paper are also satisfactory. The inner cork seal of such caps must be of the best material so that the acetic acid may not penetrate to the metal. Bottled vinegar should be pasteurized or contain a small amount of SO_2 in order that it may not become cloudy through the growth of vinegar bacteria.

Vinegar Eels. One of the most common diseases of vinegar is that caused by the growth of the vinegar eel, *Anguillula aceti*. This organism is about $\frac{1}{16}$ in. in length and is very slender. It can be seen in vinegar contaminated with it by holding a small sample to the light in a tumbler or test tube, but it is more readily observed with a hand lens. It often occurs in vinegar generators, but may also be present in the alcoholic liquid before acetification takes place. It is believed that it is distributed by spoiled fruit and by vinegar flies. Generators may become so badly contaminated with the eels that acetification is interfered with. In such cases it becomes necessary to remove the filling of the generator, to sterilize it with live steam, and to sterilize the shavings or other generator material with steam or boiling water. However, Zalkan and Fabian (1953) observed higher acetic acid production in generators containing large numbers of vinegar eels. They surmised that the eels may have acted as scavengers by keeping the generator filling free of dead vinegar bacteria. Hard cider or other liquid contaminated with the eel may be pasteurized and filtered. Tests indicate that the eel can be destroyed by a temperature of 130°F. The organism is strongly aerobic and therefore does not develop rapidly in bottled vinegar.

Slimy Generators. Vinegar generators sometimes become slimy, usually from being operated too long without cleaning the filling material. Under these conditions acetification may become very slow, or more often organisms may develop that convert the alcohol in the liquid to carbon dioxide and water and thereby greatly reduce the strength of the vinegar. The cure and prevention consist in thoroughly cleansing the generator and its contents occasionally and in operating the generator carefully, maintaining the proper balance between air supply and flow of liquid. It is usually necessary to clean the shavings or coke near the top of the generator frequently.

Wine Flowers. "Wine flowers," as noted elsewhere, may become a serious disease of fermented fruit juice and are very prevalent in cider-vinegar

factories. Storage of the fermented juice in well-filled sealed containers or the acidification of the fermented liquid by the addition of vinegar are the two most effective means of controlling the growth of wine flowers (Mycoderma).

Lactic Bacteria. In the small-scale manufacture of vinegar from fruit juices the fermented liquids will often be found to be teeming with lactic acid bacteria, commonly rod-shaped, nonmotile, and about 6 to 10μ in length and about $\frac{1}{2}\mu$ in width. These organisms often produce a disagreeable mousy flavor and odor, cause cloudiness, and interfere with acetification. The bacteria are facultatively anaerobic and develop very frequently in symbiosis with *Mycoderma vini.* Their growth is reduced by the use of pure cultures of yeast and is favored by the presence of residual sugar in the fermented liquid. Filtration and pasteurization of the fermented alcoholic liquid may be used to eliminate this organism in cases where it has become a serious disease. A very effective preventive measure is the addition of sufficient vinegar to increase the acetic acid content to about 2 per cent. One hundred parts per million of sulfur dioxide also prevents its growth.

Vinegar Flies. The vinegar fly, *Drosophila cellaris,* a very small fly that propagates in piles of fermenting pomace or in rotten fruit or in crevices around the generators, is an almost universal pest in vinegar factories. Its numbers can be reduced by strict observance of sanitary conditions in and around the plant and by disposal of the pomace in such a manner that the flies cannot find a suitable breeding place. Painting the walls with DDT will also control them, but great care must be used not to contaminate the vinegar with this poison. Screening of the outlets and tops of the generators and of the doors of the generator room will make conditions in the generator room unfavorable to its existence. The fly does not affect the quality of the vinegar but is an obnoxious pest to the workmen and probably carries vinegar eels from tank to tank in the storage room.

Vinegar Louse. This very small form of aphid develops in and around generators under certain conditions. It rarely, however, becomes a serious pest.

Analysis of Vinegar and Fermented Juices. Determination of acidity, alcohol, and extract is essential in the modern vinegar plant. The manufacturer should know the acid and alcohol content of the liquid entering the generators and of the vinegar issuing from them in order that improper functioning of the generators may be quickly detected. Pure food law standards must be met, and the manufacturer must be certain that his product conforms in composition to such regulations. Methods of determining the more important constituents are given in "Official and Tentative Methods of Analysis," Association of Official Agricultural Chemists, or in books on food analysis, such as Woodman or Joslyn.

Application of Results of Vinegar Analysis. To be of greatest value to the vinegar manufacturer the results of analysis must be properly interpreted.

Total Acid. The Federal Pure Food and Drug Act requires that vinegar contain at least 4 per cent acetic acid. Most state pure food laws are identical with the Federal law in this respect.

In distilled vinegar, total acid and volatile acid are practically identical, but in fruit vinegars an appreciable proportion of the total acidity represents fixed organic acids, such as malic, citric, and tartaric acids. For a given fruit vinegar, however, the fixed acidity is a fairly constant quantity, and if this correction factor is applied, the volatile acidity can be determined with reasonable accuracy from the total acidity. In most cases a vinegar is considered to fulfill the legal requirement in regard to acidity if it contains 4 per cent total acids calculated as acetic acid. Four per cent total acids as acetic is equivalent to "40 grains" by the Leo acid tester. Most producers do not market vinegar of less than 45 grains, 4.5 per cent total acid, as acetic.

Generators are sensitive to changes in the composition of the "wash" entering them, and after the proper proportions of vinegar and alcoholic liquid for the wash have been determined, this ratio should be maintained constant. Total-acid determinations of the two components and of the blend or wash are therefore essential.

Alcohol. Balling tests of the unfermented juice and alcohol determinations upon the fermented juice are necessary in determining the efficiency of yeast fermentation.

Alcohol determinations must be made upon the wash entering the generators and on the vinegar emerging from them in order to ensure that the conversion of alcohol to acetic acid is efficient and that the vinegar does not contain too large an amount of unconverted alcohol. Generator vinegar should contain less than 0.5 per cent of alcohol, and 1 per cent of alcohol by volume should yield at least 1 per cent of acetic acid by weight.

Sugar. A good vinegar should contain less than 0.3 per cent of sugars. A higher percentage indicates incomplete fermentation, usually caused by the presence of an excessive amount of acetic acid during yeast fermentation.

Blending. The results of analyses are very valuable in the blending of vinegar to maintain a product of uniform composition. Blending is usually necessary because of the variation in composition of the raw material and of the variation in acetification. In most cases total acid forms the principal basis for blending.

Various blending formulas may be employed, but the following formula is simple and easily applied.

Let c = per cent acid desired
a = per cent acid in vinegar of higher acidity
b = per cent acid in vinegar of lower acidity
a' = gallons of vinegar a in blend
b' = gallons of vinegar b in blend

Then

$$c - b = a'$$
$$a - c = b'$$

Example:

a = 6 per cent total acid
b = 3 per cent total acid

Required: proportion of each to give a blend c = 4 per cent.

4 − 3 = 1 gal. of vinegar a (6 per cent)
6 − 4 = 2 gal. of vinegar b (3 per cent)

This formula may be applied also to the diluting of vinegar with water, but in this case b becomes 0.

REFERENCES

Bergey, C. H., Breed, R. S., Murray, E. G. D., and Hitchens, A. P.: "Bergey's Manual of Determinative Bacteriology," Williams & Wilkins Company, Baltimore, 1939.

Braverman, J. B. S.: "Citrus Products," Interscience Publishers, Inc., New York, 1949.

Brown, J. G.: Clarification of grape juice, *Fruit Products J.*, **11**, 274–275, 1932. Includes ferrocyanide treatment to remove Fe and Cu.

Campbell, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

Cruess, W. V., and Hascal, R.: Comparative effects of acetic acid and vinegar bacteria on fermentation, *Fruit Products J.*, **3**, February, 1924, p. 22.

———, Zion, J. R., and Sifredi, A. V.: The utility of sulfurous acid and pure yeast in cider vinegar manufacture, *Ind. Eng. Chem.*, 1915, pp. 324–325.

Fabian, F. W.: Honey vinegar, *Mich. State Coll. Agr. Ext. Bull.* 149, October, 1935.

Frings, H.: Manufacture of vinegar, U.S. Patent 1,880,381, Oct. 4, 1932.

Joslyn, M. A.: Vinegar in "Encyclopedia of Technology," vol. 14, pp. 675–686, Interscience Encyclopedia, Inc., New York, 1955.

———: "Methods of Food Analysis," Academic Press, Inc., New York, 1950.

——— and Cruess, W. V.: Home and farm preparation of vinegar, *Univ. Calif. Agr. Expt. Sta. Circ.* 332, 1934.

Klöcker, A.: "Fermentation Organisms," Longmans, Green & Co., Inc., New York, 1903 (revised 1925).

Lafar, F.: "Technical Mycology," vol. 1, Charles Griffin & Co., Ltd., London, 1903.

Mitchell, C. A.: "Vinegar: Its Manufacture and Examination," Charles Griffin & Co., Ltd., London, 1926.

Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, revised 1955.

Prescott, S. C., and Dunn, C. G.: "Industrial Microbiology," McGraw-Hill Book Company, Inc., New York, 1949.

Saywell, L. G.: Clarification of vinegar, *Ind. Eng. Chem.*, **26**, 379, 385, 1934. Includes ferrocyanide treatment.

Smock, R. M., and Neubert, A. M.: "Apples and Apple Products," Interscience Publishers, Inc., New York, 1950.

Vaughn, R. H.: The acetic bacteria, *Wallerstein Labs. Communs.*, **5**(14), 5–27, April, 1942.

———: Some effects of association and competition on acetic bacteria, *J. Bacteriol.*, **36**(4), 357–367, October, 1938.

Woodman, A. G.: "Food Analysis," McGraw-Hill Book Company, Inc., New York, 1941.

Zalkan, R. C., and Fabian, F. W.: Vinegar eels, *Food Technol.*, **7**, 453, 1953.

CHAPTER 22

PICKLES

The manufacture of pickles, relishes, and condiments is one of the most important of the food industries. Although the preservation of vegetables and fruits in pickled form began as a household art, at present most of the world's supply of pickles is produced in commercial plants.

Types of Pickles. The cucumber, one of the most important raw materials used for pickles, is packed in many forms, e.g., in plain or spiced sweet vinegar in jars, kegs, or cans or fermented in spiced brine as dill pickles; packed in mustard; or in chopped form in various relishes. Green tomatoes, peppers, cauliflower, and onions are common ingredients of mixed pickles, chowchow, etc.

Sauerkraut is an extremely important pickled product. Advertising of the healthfulness of its juice has increased the demand for "kraut."

The olive is the most important fruit used in pickled form. The pickling of ripe olives is described in Chapter 9. Various fruits, but more particularly peaches, figs, and pears, are used in important quantities for sweet spiced pickles. In European countries pickled walnuts are popular.

CUCUMBER PICKLES

The cucumber, according to Le Fevre, is one of the oldest of the garden vegetables, originating in the Far East at least three thousand years ago. Although of semitropical origin, it can be grown successfully in practically any locality, provided care is taken to avoid exposure to frost.

The processes of preparing and pickling cucumbers apply in some respects to other vegetables, and for this reason cucumber pickling will be presented first.

Varieties. Cucumbers for pickling purposes should be of varieties that are firm, of regular form, and of good keeping quality. Very large cucumbers are not so desirable for pickling as the smaller sizes.

Le Fevre in 1920 recommended the Chicago Pickling, Boston Pickling, and Snow's Perfection as among the best varieties for pickling. J. E. Knott, olericulturalist at the University of California, states that these three varieties are still grown, but that the present trend is toward planting of

disease-resistant varieties such as Wisconsin SMR 9 and SMR 12, Maine 2, Ohio MR 7, Ohio MR 25, and Yorkshire.

Harvesting. In harvesting cucumbers for pickling, great care should be taken to avoid bruising, and it is customary to leave ¼ to ⅛ in. of the stem attached.

Cucumbers for pickling should be slightly underripe rather than fully mature. Cucumbers must be picked frequently as the vines blossom and bear over a period of several weeks.

The cucumbers deteriorate rapidly after picking and should be delivered to the factory or salting station as promptly as possible. Sorting to remove "nubbin" and "crook" cucumbers and to grade the cucumbers roughly for size is frequently done before salting. The larger cucumbers sorted out at this time may be barreled for preparation of dill pickles. Size grading can be done by diverging hardwood strips or pieces of pipe set in a sturdy frame. Moving rubber fingers and oscillation of the frame move the cucumbers along the slots. The smaller sizes are removed first. A more thorough size grading is made after the cucumbers have been cured in brine.

Salting and Fermentation. Cucumbers must undergo a preliminary fermentation in brine before they are placed in vinegar. A number of different types of bacteria and yeasts are present during fermentation, but the predominant and desirable organisms are lactic acid bacteria.

The fermentation and salt curing of the cucumbers are conducted in circular wooden vats from 8 to 14 ft. in diameter and 6 to 8 ft. in depth and so placed as to extend about 3 ft. above the floor of the vat room.

Brine of 40° salometer to a depth of about 1 ft. is placed in the bottom of the vat to prevent bruising of the cucumbers as the vat is filled. After the vat is filled, brine is added to cover the cucumbers. Some packers add salt at this time, relying on osmosis to form brine, but filling the vat with 40° salometer brine is considered to give better results. Brine of any desired concentration can be made by diluting a saturated brine made by the Lixate method described later in this chapter in the section on saturated brine and in a booklet of the International Salt Company, Scranton, Pennsylvania. A circular wooden head is then placed in the vat over the cucumbers and is held in place by 4- by 4-in. crosspieces secured at the ends by iron clamps. The cover is necessary to keep the cucumbers submerged in the brine, particularly during fermentation.

The concentration of the brine placed on the cucumbers is generally 40° salometer, i.e., approximately 10 per cent salt. Since cucumbers contain more than 90 per cent water, the brine rapidly decreases in concentration during fermentation and storage. A minimum concentration of 10 per cent salt (40° salometer) should be maintained during fermentation, to prevent the growth of putrefactive organisms. On the other hand, if the concentration greatly exceeds 10 per cent salt, the activity of the lactic acid organisms

is greatly retarded. During the first week of fermentation it is customary to add salt to the vat each day, draw off the brine from the bottom of the vat, and pump it over the top until the brine is of uniform concentration throughout the vat. Fabian (1944) recommends that a 40° salometer brine be applied initially and 9 lb. of salt added soon thereafter per 100 lb. of cucumbers. The brine is then increased 1° salometer per week until 60° salometer is reached. In very hot weather the rate of increase per week may have to be 5 to 6° salometer. The brine may be pumped into a box filled with crushed rock salt and fitted with a screen bottom. The brine is circulated until the desired salometer degree is attained.

Le Fevre, also Fabian, found that the addition of about 1 per cent of sugar (preferably dextrose) to the brine greatly improves the character of the fermentation because some cucumbers are deficient in sugar and are liable to develop undesirable types of bacteria unless a small amount of sugar is added to the brine. It is best added after the fermentation is well under way.

The fermentation and curing process normally requires from 4 to 6 weeks, during which period the brine is maintained at about 10 per cent salt (40° salometer) by adding salt to the top of the tank and occasionally pumping over in order to make the concentration uniform. Too frequent pumping over is considered undesirable, however, as it may stimulate the growth of aerobic spoilage organisms. When fermentation is complete, the salt concentration of the brine is gradually increased and maintained at about 15 per cent salt (60° salometer).

During fermentation and curing, the cucumbers change in color from a bright green to an olive-green or yellowish-green color, and the flesh of a completely cured cucumber becomes translucent and no longer chalky white and opaque.

The cucumbers carry considerable numbers of yeasts, bacteria, and molds. Consequently, the brine is well inoculated naturally. During the early stages of fermentation, gas-producing organisms predominate. Subsequently gas formation nearly ceases, but lactic fermentation continues. Normally the brine attains about 0.6 to 0.8 per cent total acidity expressed as lactic, although considerably higher acidity is sometimes reached. Some alcohol is formed by yeasts. Bacteria form small amounts of acetic and propionic acids.

The lactic acid bacteria occurring in pickle brines, when observed microscopically, are usually found to be long rods, frequently occurring in pairs. They resemble the so-called Tourne bacteria that cause spoiling of cider-vinegar stock and wine. The lactic bacteria are facultative anaerobes, growing better in the absence of air. They are more resistant to salt than are most spoilage bacteria; hence if the brine concentration is maintained at

40° salometer during fermentation, there is little danger of spoilage from these latter organisms.

A convenient device for preparing brine consists of an open 50-gal. barrel on a small hand truck. Salt is placed in the bottom of the barrel; a stream of water from a hose enters near the bottom, stirring the salt continuously. A hose or pipe connected near the top of the barrel conducts the brine to the vat. Operation is continuous. So-called "half-ground rock salt" is generally used. See also the section on saturated brine later in this chapter.

In filling the vat the cucumbers and salt should be weighed and the water metered in order that the resulting brine may be of the desired concentration. One pound of salt per gallon makes a brine of approximately 41° salometer.

At one time dry salting was generally used. Dry salt was added and water was extracted by osmosis from the cucumbers to form a brine. The objection to this method is that it may cause collapse of the cucumbers to such an extent that they do not regain their original size and form during processing after removal from the brine.

During fermentation the cucumbers become very permeable and consequently absorb salt rapidly to come to equilibrium with the surrounding brine.

Fabian, Bryan, Etchells, and Johnson of the Michigan Agricultural Experiment Station studied several factors important in the fermentation of cucumbers. They decided that the addition of sugar to the brine is highly desirable in order to secure optimum acidity. The sugar is added after most of the natural sugar of the cucumbers has been fermented. Peptonizing bacteria predominate in the initial stages of fermentation but practically disappear subsequently, being replaced by acid producers. Fermentation was more rapid at 30° salometer than at 40° salometer, but it is more difficult to control softening at the lower salt concentration. The addition of a small amount of acetic acid to 30° salometer brine was beneficial, but unduly retarded fermentation at 40° salometer. Some of their other conclusions are given in the paragraph on softening.

Saturated Brine. If there is on hand a supply of saturated brine, i.e., one of 100° salometer, it can be diluted to make brine of any desired salometer degree conveniently and quickly. It is conveyed to any point in the plant by pump and pipeline or by hose. Its use greatly lowers the cost of salting and brining, as much less labor is required in transportation in the plant and in handling salt.

A continuous, automatic method of making saturated brine is that known as the Lixate process of the International Salt Company, of Scranton, Pennsylvania. Coarse rock salt of best quality is held in a cylindrical tank with false bottom. There is a chamber beneath the tank for receiving the

saturated brine and a hopper at the top of the tank which automatically feeds salt to the tank as needed. To make the brine, water is automatically sprayed over the top of the column of salt and as it flows downward through the salt becomes a brine of 100° salometer when it reaches a point about 1 ft. above the bottom of the salt column. Dissolving of salt ceases at that level, and the brine is automatically filtered as it percolates downward. It emerges as crystal-clear brine, which is held in the collecting chamber or is pumped from it or flows by gravity to a storage tank.

The International Salt Company gives the following simple method of calculating the dilution of saturated brine with water to obtain a brine of any desired salometer degree. For example, assume that a pickle packer needs 700 gal. of brine of 60° salometer. Multiply 700 gal. by 60°, or rather by 60 per cent, which gives 420 gal. of saturated brine. Then 700 gal. minus 420 gal. gives 280 gal., or the amount of water to be added to 420 gal. of 100° salometer brine to produce 700 gal. of brine of 60° salometer. Similar calculations would be used for other desired brine concentrations. Several useful brine tables and other information will be found in the booklet "The Lixate Process for Making Brine," obtainable from the International Salt Company.

In California olive canneries a saturated brine is prepared by placing several tons of half-ground rock salt in an underground, concrete tank, barely covering the salt with water and allowing it to stand until a saturated brine is obtained. This brine is pumped into a storage tank and used as needed in preparing brines of 10 to 12° salometer for the canning of ripe olives or 20 to 30° salometer for the storage of raw olives for use later for pickling and canning. As brine is drawn from the salt tank it is replaced with water; and as the salt supply becomes low, more is added. Thus a continuing supply of 100° salometer is maintained.

Microorganisms of Pickle Brines. In investigations by Fabian, Bryan, and Etchells (1932) at Michigan State College it was found that there was a rapid increase in the total number of bacteria during the first 24 hr. in 40° salometer brine on fresh cucumbers. In one experiment it reached 420 million to 450 million living cells per cubic centimeter, depending on the medium used in preparing the agar plates used in counting. Within 48 hr. the total had dropped to 280 million to 300 million; at 6 days it was 80 million to 100 million; at 21 days, 3 to 3.5 million; and at 2½ months about 1.5 million per cubic centimeter. The numbers then increased somewhat owing to the development of lactic bacteria caused by the addition of 1 lb. of sugar per 45-gal. barrel. This increase occurred at 66° salometer, indicating that lack of bacterial food or fermentable sugar may be the limiting factor in bacterial growth or lack of it in strong storage brines.

These investigators state that during the first few days peptonizing bacteria are in the majority, but they then rapidly decrease in numbers and

eventually disappear, whereas the lactic acid formers gradually increase and become the predominant type. Two forms of lactic bacteria were observed: (1) those of the *Lactobacillus cucumeris* group, which form only lactic acid from the fermentable sugar, and (2) those of the *L. pentoaceticus* group (heterofermentative bacteria), which form acetic acid, alcohol, mannitol, and CO_2, in addition to lactic acid. Eventually, the "lactics" decrease in numbers, owing to the inhibitive action of the salt and probably to that of the lactic acid formed by these bacteria.

Total acidity in their experiments was greatest at about 15 days (0.7 to 0.8 per cent as lactic) and then gradually decreased, eventually to about 0.1 per cent, in spite of the high salometer degree of the brine, 65 to 68°, the decrease being due in part perhaps to scum yeasts. Addition of sugar after lactic acid production had ceased caused a resumption of fermentation and measurable temporary increase in acidity. The authors conclude that the addition of sugar in such circumstances is highly desirable.

They found that yeasts often develop in large numbers with the production of much carbon dioxide gas and reach a maximum at about 15 days; then decrease in numbers. They are quite resistant to salt and grow readily at 40 to 60° salometer.

Another important group of bacteria observed by Fabian and associates was the *Aerobacter* group, related to *Escherichia coli*, which was isolated by them from pickle brines and by Vaughn at the University of California from green-olive brines. *Aerobacter* forms hydrogen as well as CO_2; and Etchells (1941) has labeled its activity as the "hydrogen fermentation" of cucumber brines. It occurs most typically in brines of 60° salometer; hence the organism is salt-resistant.

In general, in brines of 40° salometer or higher, proteolytic and pectolytic bacteria are suppressed and the lactic bacteria are permitted to reproduce and ferment.

Etchells, Jones, and Lewis (1947) have conducted extensive bacteriological studies on the fermentation of various vegetables in brines of different concentrations. They state that the salt concentration used, rather than the kind of vegetable, was the controlling factor on the character of the microbial flora and microbial activity. In fermentations at low salt content, 5 per cent or less, large populations of acid-forming and other bacteria occurred. At or above 15 per cent salt, little or no growth of acid producers occurred. Coliform bacteria developed rapidly in brines of 2.5 to 5 per cent salt, with production of much gas, and grew in brine on shelled green peas at 20 per cent salt (80° salometer). The coliform bacteria rapidly decreased in numbers as soon as an appreciable amount of acid was formed by other bacteria. Yeasts grew and fermented over a wide range of salt concentration and appeared not to be inhibited by the acidity developed by lactic bacteria. As reported by Fabian et al., Etchells et al. found that

peptonizing bacteria, numerous in the first stages of brining, soon disappeared. Cocci were found but were very sensitive to acid though tolerant to high salt concentrations. As have others, they found that the film, or "scum," yeasts developed luxuriantly after fermentation was completed if the products were exposed to air.

Fabian and Wickerham (1935) found that at the beginning of the fermentation of genuine dill pickles Gram-positive cocci predominated. These were succeeded by Gram-positive short rods, and toward the end of the fermentation long, Gram-positive rods predominated. Bacteria of weak acid productivity were found in large numbers throughout the fermentation. Strong acid formers reached a maximum in about 8 to 10 days. Addition of 2 lb. of sugar (dextrose) per barrel increased the number of bacteria and the production of lactic acid.

See later sections in this chapter on storage, dill pickles, softening, and sauerkraut for further discussion of microorganisms of pickle brines and fermented pickles.

Storage. After fermentation is complete, the salt content of the brine is increased to 60 to 66° salometer. If properly cared for, the cucumbers may be held in this brine almost indefinitely.

If the vats are indoors, a heavy, wrinkled white film, becoming gray with age, develops on the surface of the brine. The film is made up chiefly of yeastlike organisms. E. M. Mrak of the University of California laboratory found them to belong to the genera *Debaromyces*, *Mycoderma*, and *Pichia*, for the most part, although the film is commonly termed Mycoderma. Some of these yeasts are very tolerant to salt concentration, Joslyn and the author having encountered several that grew at 20 per cent salt, nearly 80° salometer. They destroy lactic acid by oxidation and, if undisturbed, will eventually reduce the acidity so greatly that spoilage organisms will develop. Joslyn found that the acidity of 100-cc. portions of pickle brine stored at room temperature in 4-oz. bottles was reduced from 1.13 grams per 100 cc. to 0.25 gram in 26 days. In storage vats the rate is very much slower because of the great depth of the liquid; nevertheless it is appreciable.

In most factories the "scum" yeast is regularly removed by skimming in order to minimize its undesirable effect. A much more effective preventive measure consists in floating a layer of neutral mineral oil (confectioners' slab oil) about ⅛ in. thick on the surface. The objection to this measure is the danger of coating some of the cucumbers with oil when the vat is emptied. However, most of the oil may be skimmed from the surface, and the remainder floated off by adding water to fill the tank to overflowing. Vats stored in open sunlight do not develop Mycoderma film, as the sunlight prevents its growth. However, certain moldlike organisms and algae may develop rather sparsely, even in the open. Ultraviolet has been used

successfully indoors as a preventive, but the installation appears to be too costly to be practicable.

Joslyn and Cruess (1929) conducted an extensive investigation of 16 strains of film yeasts from pickle brines, particularly in respect to their oxidative properties and salt tolerance. One grew at 20 per cent salt, 75.5° salometer, in cucumber brine of pH 5.1; four grew at 19 per cent salt but not at 21 per cent; and seven were inhibited by 14 per cent or less salt. At lower pH values less salt was required to prevent growth. At 65° salometer only 0.4 per cent acetic acid was required to prevent growth of all strains, and at 44° salometer 1.0 per cent was required. The sensitiveness of these yeasts to acetic acid provides an inexpensive method of preventing their growth. At 65° salometer 0.01 per cent sodium benzoate was required to prevent their growth, and at 44° salometer, 0.06 per cent. The yeasts were able to use most sugars and many organic acids as sources of carbon. Most of the yeasts were destroyed at 60°C. in 10 min., although 30 min. at 60° was required for one and 30 min. at 65°C. for another. All were very sensitive to sunlight and failed to grow when exposed to it continuously.

Per Cent Salt and Salometer Degree. Brines are usually tested by a hydrometer known as a "salometer," or "salinometer." Salometer degree is approximately equal to per cent salt multiplied by 4, as shown in Table 48, compiled by Le Fevre. Baumé degree is also frequently used. It is approximately equal to per cent salt.

TABLE 48. PER CENT SALT AND SALOMETER DEGREE OF BRINES

Per cent salt in brine	*Salometer degree*
1.06	4
2.12	8
3.18	12
4.24	16
5.30	20
6.36	24
7.42	28
8.48	32
9.54	36
10.60	40
15.90	60
21.20	80
26.50	100

SOURCE: After Le Fevre.

Softening. Softening of cucumbers during fermentation or storage, which sometimes occurs, is usually an indication of use of a too-weak brine. Le Fevre has found that the concentration of the brine should not fall below 8 per cent salt, in order to inhibit the growth of *Bacillus vulgatus*, the organism found in his investigations to be chiefly responsible for softening.

"Slippery" pickles are those in the first stages of softening. The condition is apparently due to decomposition of pectic substances of the middle lamella. Lesley and Cruess believed from their work that the softening of dill pickles may be due to high acidity. Joslyn suggests that certain bacteria developing during the initial fermentation secrete pectolytic enzymes that later cause softening by hydrolysis of protopectin. This theory was later confirmed by Fabian and associates. They found that enzymes prepared from the spoilage bacteria caused rapid softening at or near neutrality by action on pectic substances. Young, immature cucumbers are more susceptible than others. Softening begins at the blossom end. Cucumbers badly affected by mosaic disease are very apt to soften during fermentation. Acidification of the fresh brine was found by Lesley and Cruess to inhibit subsequent softening, evidently by preventing growth of pectolytic bacteria.

Fabian and associates found that ropy (slimy) brine is caused by development of encapsulated bacteria during fermentation of brines of too low salt and acid content. They recommend rapid building up of the salt content as the best means of preventing this condition.

Blackening of the brine sometimes occurs. Fabian and associates find that it is in some cases due to formation of iron sulfide. The hydrogen sulfide comes from the decomposition of protein and the necessary iron salts from the water or equipment, such as cast-iron pumps, iron pipes, etc. In other cases the black color is a soluble pigment formed by *Bacillus nigrificans* n. sp., the necessary conditions being the presence of a sugar like dextrose, low nitrogen content, and a neutral or slightly alkaline reaction.

If the Mycoderma film is allowed to develop undisturbed, it will eventually destroy the lactic acid of the brine and induce softening and destruction of the cucumbers by spoilage organisms.

Sorting and Grading. The cured cucumbers are known as "salt stock." They are very salty to the taste, are firm in texture, and possess a pleasing fermented flavor. Before being placed in vinegar, they must be sorted, graded for size, and processed.

Sorting is done by women as the cucumbers pass before them on a broad belt.

The size grading is generally done by a revolving cylinder with holes of various sizes or by vibrating screens made of parallel strips of metal or hardwood. Some picklers grade the cucumbers for size by hand, claiming that mechanical graders do not give very uniform size grades on account of the irregular shape of the cucumbers.

Size Grades. The size grades and size designations vary somewhat in different plants, although certain terms such as Gherkins, Midgets, etc., are in common use. Cucumbers 1¼ to 2 in. long are usually termed Midgets. These may be divided into three further size grades, designated No. One,

No. Two, and No. Three Midgets, averaging about 650, 450, and 340 per gallon, respectively. Gherkins are usually 2 to 2¾ in. long and may be classed as No. One, Two, and Three Gherkins, averaging approximately 260, 225, and 160 per gallon, respectively. Cucumbers for sweet pickles and for fancy keg stock are 2¾ to 3½ in. long. According to Le Fevre the Medium-grade cucumbers are 3 to 4 in. long, and according to Shinkle 3½ to 4 in. long. The Large size is 4 in. or more in length. Le Fevre gives the Medium grade as 40 to 120 per gallon and Large as 12 to 40 per gallon.

The pickler generally speaks of size grades for cucumbers in terms of the number per 45-gal. keg, e.g., Midgets approximately 15,000 to 30,000, Gherkins approximately 7,500 to 12,000, Medium approximately 3,600 to 1,800, and Large 1,000 or less per 45-gal. keg.

Very large pickles are generally sliced or chopped and used for mixed pickles, relishes, etc.

The National Picklers' Association has adopted quality standards for cucumber pickles and salt stock. The U.S.D.A., Agricultural Marketing Administration, has established specifications for U.S. grades of cucumber pickles, sauerkraut, and some other pickled products.

Processing. The salt must be removed from the salt stock (cucumbers from brine) by soaking in water before placing in vinegar. One method consists in covering the cucumbers with hot water and bringing the mixture to 110 to 130°F., the temperature depending on the texture and size of the cucumbers. They are allowed to stand about 10 to 14 hr. with occasional stirring. Fresh water is then applied, and they are allowed to stand several hours at about 110 to 130°F. Usually a third soaking is necessary. It is customary to add about 1 lb. of soda alum to each 25 gal. of the third wash water to harden the cucumbers and about 2 oz. of turmeric to improve the color. Calcium chloride also has a hardening effect, from 0.3 to 0.5 per cent in the final wash water being sufficient.

The salt may be removed also by 1 to 2 days' soaking in cold water changed 2 or 3 times daily, followed by 10 to 12 hr. at 110 to 130°F. in hot water. If the cucumbers are very tough, it may be necessary to elevate the temperature to 140 to 150°F. for a short time; normally, however, 110 to 130°F. is sufficient.

Most other vegetables after curing in brine are soaked in several changes of cold water until practically free of salt. Alum is usually added, as for cucumber pickles. Warm water is used for soaking the salt out of onions. Cauliflower must be handled carefully and not heated to a very high temperature, so that breaking of the curds will not occur.

Sour Pickles. Distilled vinegar is used almost to the exclusion of other vinegars for pickles, because of its uniform composition, neutral flavor, light color, and low cost.

The cucumbers are often first placed for a few days in a "first" vinegar,

e.g., 40 to 50 grains strength (4 to 5 per cent acidity as acetic). This is then removed and replaced with the final vinegar of 30 to 50 grains strength. A vinegar of 40-grain acidity (4 per cent acetic acid) is generally sufficiently sour. If the vinegar is too low in acid, the pickles are apt to spoil. The final acidity should be 2.5 per cent or higher.

In one California factory the cucumbers are placed in a 55- to 65-grain (5.5 to 6.5 per cent acetic acid) distilled vinegar directly after processing and sorting. The water and juice of the cucumbers dilute the acidity of the vinegar, and the pickles absorb the vinegar. At equilibrium the average acidity of the pickles and the vinegar is 20 to 35 grains (2 to 3.5 per cent acetic acid).

Fancy bottle or small keg-pack pickles usually receive a weaker vinegar than bulk pickles in barrels.

Sweet Cucumber Pickles. The cucumbers are prepared as for sour pickles, but in order to prevent shriveling by the osmotic action of the sweet vinegar, the processed cucumbers are first stored in plain vinegar of about 5.5 per cent acidity for a few days and are then placed in a spiced sweet vinegar.

Many formulas for the preparation of the spiced sweet vinegar are in use. One consists of 8 gal. of distilled vinegar of 8 per cent acetic acid, 20 lb. of sugar (10 lb. brown sugar and 10 lb. refined white sugar), and 1 oz. each of whole cloves, coriander, mustard seed, broken gingerroot, and mace. The spices are heated in a bag in the vinegar before addition of sugar to 175 to 200°F. for about 1 hr. in a covered vessel. Any loss in volume is replaced by adding water after extraction of the spices. The spices are removed and discarded, and the sugar is dissolved in the hot spiced liquid. The vinegar should test approximately 40° Balling at 60°F. and contain 5 per cent total acid calculated as acetic acid.

Some manufacturers add sufficient sugar to 55- to 60-grain vinegar to give a sweet liquor of approximately 40° Balling. The cucumbers are stored in this vinegar for several weeks. It is then replaced with a fresh spiced vinegar made to 55° Balling with added sugar. A 100-grain (10 per cent acetic acid) vinegar made to 55° Balling with sugar will drop to about 4 to 4.3 per cent owing to dilution with the sugar.

In some cases it is necessary to proceed more slowly in order to prevent shriveling. In other words, the cucumbers are stored in a spiced vinegar sirup of which the sugar content is progressively increased by sugar additions at intervals of several days. This procedure permits the cucumbers to absorb the sugar gradually.

A few parts per million of copper is apt to impart an undesired green color to the cucumbers. Consequently it is well to avoid contact of the vinegar with copper or brass equipment. Occasionally acetic-tolerant yeasts

cause fermentation of sweet pickles. Increase of the acetic acid content is the usual preventive measure.

Usually cucumbers are mixed with other vegetables in the preparation of sweet pickles; onions, green tomatoes, and cauliflower are generally used for this purpose. Frequently whole spices also are mixed with the pickles in the final package.

Dill Pickles. Dill pickles are prepared by fermentation in a dilute brine flavored with dill herb and spices and are marketed in this brine rather than in vinegar. Such pickles are known as "genuine" dill pickles as distinguished from "process" dills made from salt stock. A weaker brine is used than for the fermentation of cucumbers for vinegar pickles because it permits rapid fermentation.

During fermentation, 45- or 50-gal. barrels are generally used as containers for the cucumbers. In filling the barrel, the head is removed and a layer of dill herb 2 to 3 in. in depth is placed in the bottom of the barrel; cucumbers are then added to fill the barrel about one-half full, and mixed dill spices are added. A layer of dill herb is placed on the cucumbers, and the barrel is filled to within 2 or 3 in. of the top. Often the dill weed is preserved in season by storing in 100-grain vinegar or in very strong brine. The vinegar pack is preferred because the flavor is retained more satisfactorily. The dry plant is also sometimes used. Dill spices are added, and a layer of dill herb placed on the cucumbers. A total of 6 to 8 lb. of green, vinegar-packed, or salted dill herb or 1½ to 3 lb. of the dry plant is used. If the brined herb is used, the brine should also be added to the cucumbers.

A total of about 1 qt. of mixed dill spices is used per 50-gal. barrel of pickles. This mixture consists of approximately equal weights of whole cloves, coriander, and black pepper and about 1 lb. of dry bay leaves per 15 lb. of the mixed whole spices.

The filled barrel is headed up, and the hoops are driven to make the barrel watertight; through a hole in the head or side of the barrel, a 40° brine (10 per cent salt) is added to fill the barrel to overflowing. The brine should be acidified with about 1 qt. of 100-grain vinegar per 10 gal. of brine in order to inhibit spoilage organisms and to stimulate the growth of desirable organisms. The barrel is stored in a warm room or in the sun, and fermentation is allowed to proceed. A temperature of about 80°F. is best, since at lower temperatures fermentation is slow and at higher temperatures spoilage or the formation of hollow pickles may occur. The bunghole is closed during violent fermentation except for a small hole through the bung to permit escape of gas. As fermentation proceeds some liquid is lost by frothing, and fresh 24° brine must be added to keep the barrel well filled. It is then tightly sealed.

In recent years tanks have been used successfully for the fermentation of

genuine dill pickles in bulk. In one large plant tanks of about 5,000-gal. capacity were used in 1955.

The pickles should be ready for use within 6 weeks after beginning of the fermentation.

Dill pickles attain about 1½ per cent of total acid expressed as lactic acid. The barrels must be kept well filled and sealed after curing is complete; otherwise film yeasts will destroy the acidity and spoilage bacteria will then develop.

Dill pickles also frequently exhibit softening or slipperiness at the blossom end, although they are normal in all other respects. Lesley and the author concluded that this deterioration might in some cases be due to use of immature cucumbers plus hydrolysis of pectic substances by high acidity. Others, including Joslyn and Fabian, have believed that it may in many cases be caused by enzymes elaborated by spoilage bacteria shortly after filling of the barrels, for at that time the acidity is sufficiently low to permit the growth of such organisms. Acidification of the initial brine, as previously described, greatly reduces loss, tending to confirm this theory, and Fabian has proved its validity. Probably natural pectin-splitting enzymes of the cucumbers also are involved in this phenomenon. It is recognized that use of immature cucumbers predisposes the product to this form of deterioration.

Dill pickles should be consumed within a few months after curing is complete, as they do not keep so well as vinegar pickles. If they are to be held for a relatively long period, the salt concentration of the brine should be increased to about 30° salometer. They are also preserved by canning or bottling in the manner described in the following paragraph.

So-called "process" dill pickles are made by soaking salt-stock cucumbers in hot water to remove salt followed by storage in barrels or tank with dill plant, dill spices, and brine acidified with vinegar. They are inferior to the "true" dill pickles previously described.

Canning and Bottling. Cucumber pickles of all kinds and mixed pickles are now successfully canned in heavily lacquered cans.

In one California factory the cucumbers are packed into the cans carefully by hand; brine, vinegar, or spiced sweet vinegar, as the case may require, is added. The cans are given a very thorough exhaust at 200°F. (about 8 to 10 min.), then are sealed, and no further sterilization is given. Exhausting removes air, expands the contents, and thus creates a vacuum in the can. Good results are also obtained if, after exhausting and sealing, the sealed cans are processed for about 10 min. in water at 185 to 200°F.

Pickles packed in glass are usually not sterilized. The pickles are packed into the jars by hand, according to a definite pattern. The packed jars are filled with vinegar or sweet spiced vinegar and sealed, usually in vacuum. No heating is required for glass-packed pickles.

As the brine in which the pickles have been fermented is very cloudy, it should be filtered before addition to glass-packed dills. A freshly made brine acidified with vinegar may be used in place of the fermented brine.

OTHER VINEGAR PICKLES AND RELISHES

Many kinds of fruit and vegetable pickles are produced commercially.

Onions. Small onions are first trimmed and peeled. They are generally stored in several changes of water for 3 or 4 days and are then, in some pickling plants, placed in brine strong enough to prevent fermentation, i.e., about 60° (15 per cent salt), and stored until they have become translucent or until used for pickles. The brine is strengthened by addition of salt as required. The salt is leached from the onions with warm water before they are placed in vinegar. Onions are also prepared for pickling by fermentation in brine of 10 per cent salt (40° salometer), as described for cucumbers earlier in this chapter.

Green Tomatoes and Mango Peppers. These are usually handled in the same manner as cucumbers, but in strong brine in order to minimize gaseous fermentation.

Cauliflower. Cauliflower in some factories is placed at once in a strong brine, 60° salometer, and fermentation is prevented by maintaining the brine at this concentration until the cauliflower is cured. Le Fevre, however, recommends that cauliflower be cured in a 10 per cent brine (40° salometer) and prepared for the vinegar in the same manner as cucumbers.

String Beans. These are usually cured in barrels after mixing with about 60 lb. of salt per 50-gal. barrel. The salt withdraws juice from the beans to give a strong brine. The beans may also be cured by fermentation in brine in the same manner as cucumbers.

Small Peppers. Small peppers for Tabasco sauce, etc., are fermented in wood in brine of about the same concentration as that used for cucumbers. They are also packed fresh in vinegar. Or they are barreled directly in strong vinegar containing some added salt, the purpose being to prevent gaseous spoilage.

Processing and Addition of Vinegar. These various vegetables after curing in brine are prepared and stored in vinegar in much the same manner as described elsewhere for cucumber pickles.

Sweet Fruit Pickles. Peaches, pears, figs, watermelon rind, and grapes are often prepared as sweet pickles. The following method is satisfactory: The fruit is cooked in water or in dilute sirup until tender; then boiled a short time in a sirup of sugar 24 lb., water 2 gal., vinegar 1 gal., and 1½ oz. each of whole cloves, stick cinnamon, and ginger; and allowed to stand overnight. The sirup is drawn off and concentrated to a boiling point of about

219 to 220°F. and returned to the fruit. The fruit and sirup are heated to boiling and sealed boiling hot in jars or cans.

Also fruits are often canned in a sirup of 40° Brix containing about 1 gal. of 100-grain vinegar to 9 gal. of sirup. The sirup is spiced as described above. The fruit is canned, exhausted, sealed, and processed in the usual manner. Type L cans should be used to minimize corrosion. This product is increasing in popularity. Whole lye-peeled peaches are canned in this manner in California (Chapter 8).

RELISHES

Most commercially prepared relishes are prepared from or contain appreciable amounts of pickled vegetables. Familiar examples of relishes are chowchow, piccalilli, Mexican hot, and mustard pickles (for recipes and formulas see references at end of this chapter).

SAUERKRAUT

"Kraut" is made in practically every vegetable-growing section of the United States and Europe by a process which is very simple and which can be conducted on either a factory or household scale. It affords a convenient means of conserving surplus cabbage during periods of temporary overproduction.

Coring and Shredding. Only sound firm heads should be used. They are usually stored in a well-aerated location for several days to permit slight wilting so that there will be less breakage during cutting. The outer leaves are removed by hand, and the core is reamed by a rapidly revolving conical knife which shreds the core and leaves it in place. The cored cabbage is cut into thin shreds by thin curved knives attached to a revolving metal disk about 3 ft. in diameter housed in a vertical metal cylinder into which the heads of cabbage are fed. The sliced cabbage falls on a conveyer which carries it to the fermenting tanks, or it is placed in special carts and moved to the vats or tanks.

Salting. Cabbage is converted into sauerkraut by a lactic acid fermentation, the presence of a moderate concentration of salt being necessary to reduce the growth of spoilage organisms and to promote the growth of lactic acid bacteria. A great deal of research has been conducted on the bacteriology of kraut making by Fred, Peterson, and others at the Wisconsin Agricultural Experiment Station (see references at end of chapter) and Pederson at the New York Station.

The usual proportion of salt is 2½ per cent by weight. The salt is well mixed with the shredded cabbage as the tank, cart, or other container is filled.

Large circular wooden vats are used for commercial fermentation and storage, and heavy pressure is applied to the cabbage by a false wooden head.

Fermentation. The pressure and salt extract juice from the cabbage, and a brine, which completely covers the cabbage, is soon formed. Bacteria and yeasts develop rapidly, and gas evolution is vigorous during the first stages of fermentation.

Although yeasts are present in considerable numbers and may produce small amounts of alcohol, particularly during the initial stages of the fermentation, the predominant organisms are lactic acid formers; the *Leuconostoc* group of cocci is always present and is responsible for considerable gas formation as well as lactic and acetic acids, alcohol, and mannitol. Butyric acid bacteria are highly undesirable. If the development of yeasts, *Aerobacter*, and butyric organisms can be prevented, or at least reduced to a minimum, the quality of the product will be improved correspondingly.

The Wisconsin investigators found that most of the organisms were rod forms with relatively few coccus forms. The majority were Gram-positive and catalase-negative. About two-thirds formed gas from dextrose, and many formed mannitol from levulose. Most of the acid formed was lactic. Some acetic acid was formed. Pederson at the New York Experiment Station has also studied kraut-fermentation organisms. He reports that *Leuconostoc mesenteroides* initiates the fermentation and forms 0.7 to 1.0 per cent total acidity expressed as lactic acid. Much of the pleasing flavor and "aroma" of sauerkraut are due to its activity. It is usually followed by *Lactobacillus cucumeris* and related forms of Gram-positive lactic acid producing short rods that can increase the acidity to about 1.5 per cent. They do not form gas. They reach a maximum at 3 to 5 days and are followed by another group of lactic acid bacteria, of which *Lactobacillus pentoaceticus* is typical. These organisms form lactic acid, acetic acid, alcohol, CO_2, and mannitol and are powerful fermenters, the final acidity in some instances being above 2 per cent. They form rods that are longer than those of the *Lactobacillus cucumeris* group. The optimum temperature for growth and fermentation for *Leuconostoc mesenteroides* is about 75 to 77°F., *L. cucumeris* about 85 to 86°F., and for *L. pentoaceticus* about as for *L. cucumeris*. For further information on kraut fermentation and its microorganisms, see Pederson's publications listed at end of the chapter.

Le Fevre recommends the addition of pure cultures of selected lactic acid organisms, as a result of an improved product obtained by the use of pure cultures in his commercial-scale experiments.

The organisms were grown in sterilized cabbage, and this culture in turn was used for the inoculation of tanks of shredded cabbage. He believes that tanks started with pure cultures could be used for the inoculation of subsequent tanks, as is done in the fermentation of vinegar stock, wine, etc.,

and states that pure cultures are used regularly and with marked success in Europe. Suitable cultures may probably be had through the Department of Bacteriology, University of Wisconsin, Madison, Wisconsin, or the Agricultural Experiment Station, Geneva, New York.

A temperature of 65°F. is the optimum for quality in kraut fermentation. If the cabbage is cold when shredded, it is desirable to warm it to 65 to 70°F. in the tanks and to warm the fermentation room, if it is very much below 65°F.

The acidity rapidly increases during fermentation and frequently reaches 1.8 per cent expressed as lactic acid.

Care after Fermentation. After fermentation is complete the tanks should be sealed to exclude air, the presence of which permits molding, growth of film yeasts, and bacterial spoilage. Where a liquid covering only is used, this must be skimmed frequently to prevent excessive growth of the destructive film yeast; or the liquid must be covered with a layer of neutral mineral oil.

Spoilage and Discoloration of Sauerkraut. Two common forms of discoloration are recognized. One of these is the development of a pink color, the other of a brown color.

The pink color is frequently caused by growth of a pink yeast. Fred and Peterson have made an exhaustive study of this problem and have found normal sauerkraut and pink sauerkraut from the same factory to have the following compositions:

Analysis	Normal sauerkraut	Pink sauerkraut
Water	90.600%	88.000%
Volatile acid as acetic	0.247%	0.255%
Fixed acid as lactic	1.026%	1.426%
Alcohol as ethyl alcohol	0.727%	0.978%
Yeast cells per cubic centimeter	3,600,000	91,000,000

The pink sauerkraut contained a very large number of yeastlike cells from which several strains of pigment-forming yeasts were isolated. When inoculated into shredded cabbage, positive results were obtained.

The brown discoloration of sauerkraut usually occurs after removal of the kraut from the vat and is apparently an oxidation phenomenon. Prompt use or canning of the sauerkraut after opening the vat will avoid browning.

Soft sauerkraut may be due to the activity of aerobic organisms developing in air pockets, or in cabbage that is not tightly packed, or to uneven salting, or to too high a temperature. Off flavors may be caused by faulty fermentation or by flavors and odors absorbed from faulty barrels or tanks. At high temperatures, according to Pederson, *L. cucumeris* may encapsulate

and form slime, a condition that may render the product unsalable, although harmless to consumers.

Canning. There is a good demand for canned sauerkraut, since the canned product is in convenient form for shipment and use and is not so subject to deterioration and spoilage as the bulk sauerkraut.

The sauerkraut used for canning is ordinarily not cured for so long a time as that to be sold in bulk, as the canner desires a product of lighter color and lower acidity than the bulk sauerkraut.

It is heated to boiling in steam-jacketed kettles and is packed hot into cans in its own brine (hot fresh brine being added if necessary). The cans are sealed and, in some plants, sterilized under steam pressure. In other plants the kraut is heated in jacketed stainless-steel or glass-lined kettles, drained, and canned. The cans are filled with the hot juice, given an exhaust, sealed, and processed a short time in steam—long enough for the contents to reach 180°F. The high acidity of the sauerkraut facilitates sterilization, but heat penetration is slow.

Some loss of canned sauerkraut has occurred from the development of hydrogen gas by action of the acid of the sauerkraut on the tin plate. A freshly opened can of sauerkraut possesses a disagreeable odor, but this odor disappears during cooking. Bacterial spoilage is very rare.

Sauerkraut Juice. The juice that forms during fermentation of kraut, or that obtained by pressing the finished product, is rather popular as a beverage. Some is used in the fresh or raw condition, and some as a canned or bottled product preserved by pasteurization.

Lettuce Kraut. Cruess and Gililland (1939) found that excellent sauerkraut can be made from firm varieties of lettuce by the use of methods described in this chapter for making cabbage kraut. Lettuce kraut is of much milder flavor than cabbage kraut. It behaves well in canning.

PRESERVATION OF OTHER VEGETABLES BY SALTING AND FERMENTATION

In European countries, particularly Holland and Belgium, many varieties of vegetables are preserved commercially and in the home by salting and by fermentation in brine. During the First World War these methods were widely advocated by the U.S.D.A. and state colleges of agriculture for use in the home to conserve the surplus of war gardens and to conserve tin plate.

Practically all vegetables can be preserved by mixing with one-fourth their weight of salt or by lactic fermentation in a 5 per cent brine. For further details see Round and Lang; Etchells, Jones, and Lewis (1947); and Joslyn and Cruess.

OLD-FASHIONED CUCUMBER CHIPS

A popular cucumber product for use in salads, sandwiches, and in other manners is one known by several names, such as "bread and butter pickles," "cucumber chips," "home-style sliced pickles," etc. Cruess and Joslyn describe one method of making them about as follows:

Cucumbers of medium-large size, 1 to 1½ in. in diameter, are sliced into circular disks about ¼ in. thick. If cut too thin the slices are apt to break during handling and processing. Heat to 125°F. in a liquid consisting of 25-grain vinegar containing enough salt to bring the salometer degree to 25 to 30°. This liquid should also contain enough turmeric to impart a slightly yellow color to the slices and a small amount of alum to make them crisp. Allow to stand overnight. Discard the liquid. Prepare a sweet, spiced vinegar as follows: To each gallon of 50-grain distilled vinegar add 5 lb. of sugar, 3½ oz. of whole mustard seed, 3½ oz. of celery seed, and 1 to 2 oz. of turmeric. Heat the cucumber slices in this liquid to 160°F. until tender; do not heat too long. Pack the slices in jars. Heat the liquid to about 185 to 190°F. and add it to the jars scalding hot. Seal. An alternative method consists in packing the slices in the jars without preliminary heating, adding the liquid heated to about 185°F., sealing jars, and pasteurizing the jars at 160°F. for about 20 min.

Various other methods are in use commercially for preparing these "old-fashioned chips." The principal precaution is to avoid heating the slices so long or at such a high temperature that they become soft.

SALTED VEGETABLES

During the Second World War large quantities of peas and corn and lesser amounts of other vegetables were preserved by barreling with dry salt or very heavy brine. Fermentation was prevented, as it would change the color adversely. The salted vegetables were used by soup manufacturers and canners of other products. For some products it is not necessary to leach out the salt, e.g., if a small amount of salted peas is added to vegetable soup (see Fabian, 1943). Cored whole red pimientos are preserved in heavy brine for use in stuffing Spanish-type, pitted green olives. A considerable quantity is also diced and preserved by dry salting for use in various dairy products and processed food products. The latter product is diced before salting; also, it may be partially dehydrated before salting.

GREEN OLIVES

Spain produces large quantities of pickled green olives, the United States importing from that country approximately as many gallons of green olives

as the quantity of ripe olives produced in California. Green olive pickling has also become an important industry in California.

Varieties. The Sevillano (Queen) is the largest and most popular olive used for green pickling, and the Manzanillo is second in importance. Both varieties have been described in Chapter 9. In California the Mission variety is also used to some extent for green pickling.

Harvesting. The olives are allowed to attain approximately full size but are gathered before they have begun to develop color or have softened. Bruising is avoided, and the fruit is placed in the pickling vats as promptly as possible. In California the green olives are graded for size before placing in the vats; in Spain size grading is done after pickling is complete.

In some sections of Europe the olives will become infested with the larvae (maggots) of the olive fly if they are allowed to remain on the tree too long.

Lye Treatment. In Spain the olives are placed in shallow vats and covered with a dilute sodium or potassium hydroxide solution (2 per cent sodium or potassium hydroxide) at room temperature. This solution is allowed to penetrate about two-thirds, but not completely, to the pits of the fruit. In California circular redwood vats, each holding several tons of size-graded olives, are used for lye treatment.

If the lye solution is too strong or too prolonged, all the bitterness is removed, and the flavor, texture, and color of the finished pickles are apt to be inferior. Too strong lye (above about 1.7 per cent) causes cleavage of the flesh and water blistering of Sevillano olives in California, a serious cause of loss occasionally. By removing the lye solution before it has completely reached the pits, a small amount of untreated bitter flesh remains and imparts a pleasing flavor to the pickled olives. In California, lye solutions for green olives vary from 1.25 to 2 per cent according to Vaughn et al. (1943). For a "quick cure" the lye penetrates nearly to the pit; for a normal cure, about two-thirds to three-fourths to the pit.

The Manzanillo variety is treated more thoroughly with lye than the Sevillano. Dilute phenolphthalein solution applied to the cut surface of an olive will indicate the depth of lye penetration.

Washing. The lye is then removed, and the olives are covered with water, which is changed several times daily until the fruit is nearly free of lye. Washing will normally require about 1 to 1½ days.

Normally, the treated flesh of the olives is quite alkaline in reaction at time of barreling, more so in Spain than in California. In Spain many olives give a very strong reaction with phenolphthalein when they are removed from the vat. In California the washing is carried somewhat further than in Spain, and the treated flesh of most of the olives gives only a moderate to faint test with phenolphthalein. Most of the fermentable carbohydrates will be leached from olives washed too long; if they are not washed long enough, the high alkalinity may favor spoilage bacteria with subsequent

spoilage. Also, if the olives are washed too long or are exposed to air unduly during washing, they are apt to become gray in color.

Barreling and Fermentation. From the lye-treating vat or tank the olives are transferred in California to 50-gal. oak barrels, or in Spain to bocoys of

FIG. 103. *Upper:* Vats for treating green olives with lye or for fermenting green olives. *Lower:* Barrels of green olives undergoing fermentation. (*Lindsay Ripe Olive Co., Lindsay, Calif.*)

180- to 185-gal. capacity. The Spanish casks are made of oak or chestnut. To fill the barrels or bocoys the heads are removed. After filling, the heads are replaced and the hoops driven into place; in Spain by a hammer and hand hoop iron, in California by a mechanical hoop driver.

Brine is then added through a side bung to fill the barrel or bocoy. In Spain a brine of 44° salometer is used for both Sevillano and Manzanillo

olives. In California a 50 to 54° salometer brine is added to Manzanillos in some plants, in others a somewhat weaker brine of about 45° salometer. To barreled Sevillano olives in California it is customary to add a rather weak brine, 20 to 30° salometer, and then to add additional salt daily or every other day to the brine as follows: Ground rock salt is placed on the head of the barrels resting upright. The head is also covered with a layer of brine about ½ in. deep. Two small holes are bored in the head. Salt dissolves, and the strong brine flows downward into the barrel; weaker brine flows upward to the head. Convection currents thus set up distribute the strong brine through the contents of the barrel. When the brine attains 28 to 30° salometer and holds that concentration permanently, no more salt is added.

In any event, both in Spain and in California the aim is to attain a salt content corresponding to about 28 to 30° salometer for both major varieties of green olives, as this range gives an agreeable taste and minimizes bacterial spoilage.

The barrels are completely filled, bunged tightly, and placed in a sunny position for natural incubation; but as olives are harvested in October and November, cloudy and cool weather often greatly retards fermentation. The fermentation is very slow, compared with that of cucumbers, probably owing to scarcity of nitrogenous bacterial food substances (Figures 103 and 104).

In favorable weather, lactic bacteria, some yeasts, and some gas-forming bacteria of the *Aerobacter aerogenes* group develop fairly rapidly. Eventually the lactic forms predominate and take over the fermentation. Occasionally butyric spoilage bacteria develop and may completely spoil the flavor of the olives. Most green olive processors do not add starters of pure cultures of lactic bacteria, although they often add a quart or two of sound brine per 50-gal. barrel from the previous year's pack or from a barrel of the current season in active fermentation.

While gas production during the initial stages of fermentation is customary, if it is excessive it will cause blistering and gas pockets. *Aerobacter aerogenes* and yeasts are often the cause of gas production, although heterofermentative (gas-producing) lactic bacteria may also be involved. Homofermentative (nongas formers) are preferred; hence the addition of pure cultures would appear desirable, although experiments by R. Vaughn and the author have not been so successful as desired.

Normally the lactic fermentation gets well under way in October and November, but cold weather then arrests it until spring. In some plants, as a result of the author's experiments, several hundred barrels of the olives are incubated in a warm room at 75 to 80°F. to hasten fermentation.

Some California plants now ferment much of their pack in closed redwood tanks, each holding several tons of olives. Steam pipes beneath the tanks

Fig. 104. Casks of green olives in yard of Olmeda Co., near Seville, Spain.

maintain a favorable temperature, or the tanks are stored in a heated room.

Sevillano olives ferment more rapidly than the Manzanillo. The total acidity expressed as lactic should, and usually does, exceed 0.60 per cent; it may reach 1.25 per cent.

It is customary in California to add dextrose (pure commercial corn sugar) to the barreled olives after fermentation has proceeded for several weeks in order to provide fermentable sugar, in which the olives are often deficient. In Spain this addition is apparently unnecessary. Sucrose is also satisfactory, according to Vaughn et al. (1943).

Frequent determinations of total acidity, salometer degree, and pH value are made on the brines during fermentation. The pH value should drop rapidly to 3.8 or less.

Spoilage during Fermentation. Occasional barrels of olives develop a "sagey" off odor and flavor, termed "zapatera" spoilage. If badly affected, the olives become a total loss; if the spoilage is discovered in time, the olives can be saved by addition of vinegar or lactic acid to reduce the pH value below 4.0. Ball, confirmed later by Vaughn, showed that zapatera spoilage occurs only at pH values above 4.2; hence maintenance of pH values below 4.2 is advisable.

Another occasional spoilage is caused by butyric bacteria. If start of lactic fermentation is delayed unduly, the continued high pH value permits various butyric bacteria to develop and produce a penetrating, very disagreeable butyric odor and flavor, rendering the olives inedible. Inoculation with lactic cultures or initial acidification will preclude this spoilage.

"Fisheye" spoilage is evidenced by gas pockets and gas blisters. It is usually caused by bacteria of the *Aerobacter* group, although yeasts are also

sometimes responsible. Initial acidification and high initial salt content of the brine will discourage this form of spoilage.

Off Color. If the olives are exposed unduly during washing after lye treatment, the color darkens, and after fermentation is complete the olives are apt to be gray in color, a defect that very greatly affects their market quality and value. Also, if washing is unduly prolonged, e.g., to 2 or 3 days, they may turn gray owing to oxidation. Borbolla et al. (1956) state that the addition of ascorbic acid will maintain the desired color.

Pitting and Stuffing. Many Manzanillo olives are pitted after fermentation is complete—in Spain by hand pitters, in California by high-speed automatic pitters. The pitted olives are stuffed with strips of red pimiento allspi previously preserved in heavy brine. Small onions, brined zucca melon, and almond meats are also used. In Spain the stuffed olives are fermented several weeks in 30° salometer brine in barrels before packing or shipping.

Sorting. In Spain the olives are size-graded after pickling; in California, before pickling. In both areas, however, the pickled olives are carefully sorted to remove those that are off color, blemished, and otherwise defective. The defective olives may be pitted and made into minced olives or relish.

Packing. At time of packing the olives should be free of fermentable sugar; they should also have lost their raw taste and attained a yellow-green ("olive-green") color. The total acidity should be above 0.75 gram per 100 cc. as lactic. The flavor should be pleasing, and the texture firm and crisp (not tough or soft).

The sorted olives are packed carefully by hand, often to a definite pattern, in glass jars. The jars are then filled automatically with water or brine and emptied automatically in order to rinse them free of adhering sediment.

The jars are then filled with brine of about 28° salometer. Some packers add 0.2 to 0.5 gram of lactic acid per 100 cc. of brine, particularly if the olives are below optimum acidity. One packer adds 0.1 to 0.2 gram of acetic acid per 100 cc. as distilled vinegar. The jars should then be vacuum-sealed to discourage growth of aerobic yeasts; but sealing at atmospheric pressure is also common.

Although it is not customary to pasteurize the bottled olives, sedimentation from bacterial growth is less apt to occur if the packed olives are pasteurized at 140°F. or brined at 175 to 180°F.

Research on Green Olives in Spain. At the Instituto de la Grasa in Seville, Spain, Borbolla y Alcala, Herrera, Guzman, and others have conducted a great deal of research on the problems that have arisen in the commercial production of Spanish-type, fermented green olives. These have included the effect of the initial acidity of the brine, initial salt concentration, initial sugar concentration in the fruit, addition of various sugars to the brine, comparison of various strains of lactic acid bacteria for the fer-

mentation of green olives, the role of yeasts, and changes in sugar content of the olives during lye treatment and leaching with water to remove the lye. Borbolla and associates have recently published a book describing the Spanish methods and reporting fully on their experiments (see references).

REFERENCES

BELL, T. A., ETCHELLS, J. L., and JONES, I. D.: Softening of commercial cucumber salt stock in relation to polygalacturonase activity, *Food Technol.*, **4**, 157–160, 1950.

BIDAN, P., ANDRE, L., and BAHRET, A.: Étude sur la preparation et conservation des cornichons en saumure, *Ann. technol.*, **3**, 177–205, 1953. Address, Institut National de la Recherche Agronomique, Paris.

BORBOLLA Y ALCALA, J. M. R.: Problemas en el aderezo de aceitunas, *Asoc. Export. Aecitunas Sevillanas Bull.*, Seville, 1951. Covers various problems of green-olive preparation. See also a book by same author and associates, 1956, covering all phases of the industry, "El Aderezo de Aceitunas Verdes."

———, HERRERA, C. G., and GUZMAN, R.: Buffer system of brine solutions for pickled green olives, *Ind. Eng. Chem.*, **44**(9), 2227, 2229, April, 1952. Address, Instituto de la Grasa, Seville, Spain.

CAMPBELL, C. H.: "Campbell's Book: Canning, Pickling, and Preserving," revised by R. A. Isker and W. A. Maclinn, Vance Publishing Co., Chicago, 1950.

CRUESS, W. V.: Olive products, *Ind. Eng. Chem.*, **33**, 300–303, 1941.

———: Use of starters for green olive fermentation, *Fruit Products J.*, **17**(1), 1–12, 1937.

———: Pickling green olives, *Univ. Calif. Agr. Expt. Sta. Bull.* 498, 1930.

———: Pickling of olives in Mediterranean countries, *Univ. Calif. Agr. Expt. Sta. Circ.* 278, 1925; also *Bull.* 498, 1930.

——— and GILILLAND, R.: Lettuce kraut and juice, *Fruit Products J.*, **18**, 231, 232, 251, 1939.

ETCHELLS, J. L., FABIAN, F. W., and JONES, I. D.: The aerobacter fermentation of cucumbers during salting, *Mich. Agr. Expt. Sta. Tech. Bull.* 200, June, 1945.

——— and JONES, I. D.: Characteristics of lactic acid bacteria from cucumber fermentations, *J. Bacteriol.*, **52**, 593, 599, 1946.

——— and ———: Preservation of vegetables by salting or brining, *U.S. Dept. Agr. Farmers' Bull.* 1932 (revised 1943).

———, ———, and LEWIS, W. M.: Bacteriological changes during the fermentation of certain brined and salted vegetables, *U.S. Dept. Agr. Tech. Bull.* 947, October, 1947.

FABIAN, F. W.: pp. 1888–1936 in M. B. Jacobs (ed.), "The Chemistry and Technology of Food and Food Products," vol. 3, Interscience Publishers, Inc., New York, 1951.

———, and BLUM, H. B.: Preserving vegetables by salting, *Fruit Products J.*, **22**(8), 228–236, April, 1943.

———, BRYAN, C. S., ETCHELLS, J. L., and JOHNSON, E. A.: Experimental work on cucumber fermentation, *Mich. Agr. Expt. Sta. Tech. Bull.* 126, 1932; *Tech. Bull.* 140, 1934; *Tech. Bull.* 157, 1938. Also *J. Bacteriol.*, January, 1938.

———, KREHL, C. E., and LITTLE, N. W.: The role of spices in pickled-food spoilage, *Food Research*, **4**(3), 269–286, 1939.

——— and WICKERHAM, L. J.: Genuine dill pickles: a biochemical and bacteriological study of the curing process, *Mich. Agr. Expt. Sta. Bull.* 146, 1935.

FRED, E. B., and PETERSON, W. H.: Pink sauerkraut: its cause and prevention, *Canner*, **53**(11), 39–40; (12), 37–39, 1921.

Gililland, H. R., and Vaughn, R. H.: Characteristics of butyric acid bacteria from olives, *J. Bacteriol.*, **46**, 315–322, 1943.

Hohl, L. A.: A study of organisms found in lactic acid fermentation of lettuce, *Food Research*, **7**(4), 309–312, 1942.

——— and Cruess, W. V.: Lettuce kraut, *Proc. Inst. Food Technol.*, June, 1940, pp. 159–166.

Jones, H. A., and Rosa, J. T.: "Truck Crop Plants," McGraw-Hill Book Company, Inc., 1928.

Joslyn, M. A.: Some observations on the softening of dill pickles, *Fruit Products J.*, **8**, 19, and **9**, 16, 1929.

——— and Cruess, W. V.: Comparative investigation of film forming fungi, *Hilgardia*, **4**(9), 201–240, 1929.

——— and ———: Home and farm preparation of pickles, *Univ. Calif., Coll. Agr., Ext. Circ.* 37, 1933.

Kertesz, Z. I.: "The Pectic Substances," Interscience Publishers, Inc., New York, 1951.

Le Fevre, E.: Fermented pickles, *U.S. Dept. Agr. Farmers' Bull.* 1159, 1920.

"The Lixate Process," International Salt Co., Scranton, Pa., 1944.

Nortje, B. K., and Vaughn, R. H.: The pectolytic activity of species of the genus Bacillus, *Food Research*, **18**(1), 57–69, 1953.

Parmele, H. B., Fred, E. B., Peterson, W. H., McConkie, J. E., and Vaughn, W. E.: Relation of temperature to fermentation of sauerkraut, *J. Agr. Research*, **34**, 79–95, 1927; **35**(11), 1021–1038, 1927.

Pederson, C. S.: The gas producing species of Lactobacillus, *J. Bacteriol.*, **35**, 95–108, 1938.

———: A study of the genus Lactobacillus plantarum, *J. Bacteriol.*, **28**, 267, 1936.

———: Floral changes in the fermentation of sauerkraut, *N.Y. State Agr. Expt. Sta. Tech. Bull.* 168, 1930; also *Tech. Bull.* 169; *Bull.* 614, 1932.

——— and Albury, M.: Effect of temperature on bacteriological and chemical changes in fermenting cucumbers, *N.Y. State Agr. Expt. Sta. Bull.* 744, 1950.

Smyth, H. F.: A bacteriologic study of the Spanish green olive, *J. Bacteriol.*, **13**, 9, 56, 1927.

Vaughn, R. H., Douglas, H. C., and Gililland, R.: Production of Spanish type green olives, *Univ. Calif. Agr. Expt. Sta. Bull.* 678, April, 1943.

West, N. S., Gililland, R., and Vaughn, R. H.: Characteristics of coliform bacteria from olives, *J. Bacteriol.*, **41**, 341–352, 1941.

CHAPTER 23

UTILIZATION OF WASTE FRUITS AND VEGETABLES AND DISPOSAL OF WASTES

In the canning, drying, and preserving of fruits and vegetables there accumulate peels, cores, pits, vines, cobs, and other waste materials that must either be utilized in some manner for by-products, fed to livestock, or disposed of as garbage.

The utilization of fruit pits has become an important industry in California, and at present nearly all the apricot pits from the drying and canning industries are converted into valuable by-products.

Character of Fruit and Vegetable Wastes. The more important wastes are the following:

1. Fruit wastes:
   a. Peels, cores, and trimmings.
   b. Pits from apricots, cherries, and peaches. Cull nuts.
   c. Grape seeds, stems, and skins (pomace).
   d. Cull fruit from fresh-fruit packing houses.
   e. Overripe and blemished fruit from canneries, driers, etc.
2. Vegetable wastes:
   a. Tomato seeds, skins, and trimmings.
   b. Asparagus waste from canning.
   c. Cobs and husks from corn canning.
   d. Vines and pods from pea canning.
   e. Wastes from canning or drying miscellaneous vegetables, such as spinach, pumpkin, sweet potatoes, and beans.

Cereal and field-crop wastes, such as cottonseed, corn germs, and wastes from fish and meat packing, could also be added to the list, but these do not come within the scope of this book. In addition to the solid wastes listed above, fruit- and vegetable-processing plants must dispose of large volumes of liquid wastes from washers, peelers, blanchers, and cleanup of floors, etc. Although this waste is chiefly water, it carries appreciable quantities of dissolved and finely divided solid organic matter that is fermentable or putrescible.

FRUIT BY-PRODUCTS

The utilization of waste and cull fruit in the preparation of certain products is discussed in other chapters. Among the products made from fruits may be mentioned the canned, the juices, concentrates, jams, jellies, and vinegar.

Fruit Peels and Cores. A large part of the peels and cores from applesauce canneries and apple driers are now utilized for the production of vinegar or for jelly stock. If this material is to be used for vinegar making, it should be crushed and pressed promptly so that growth of wild yeasts will not occur with loss of sugar nor acetification proceed to the point at which the activity of true yeasts is prevented or seriously retarded.

At one time considerable quantities of apple peels and cores were dried for the use of jelly manufacturers in making a low-priced jelly for bakers' use. The dried material was cooked with water to give a jelly juice that could be combined with various juices, sugar, and citric acid and boiled to the jellying point. Or it was artificially flavored and colored. However, since powdered pectin has become available, less of the dried apple waste is used by jelly manufacturers. Some peels and cores are used for the production of apple pectin, as outlined in Chapter 14. Citrus peels are used for this same purpose.

Utilization of Pineapple Waste. As previously outlined, pineapple peels and cores from canning are now utilized for making a sirup used in pineapple canning, as described in the following section, for the making of vinegar, and in other ways. Much of the juice at one time was fermented and distilled for industrial alcohol, denatured by the addition of wood alcohol and ether. It is reported that it was used in gasoline engines in the Hawaiian Islands.

Following the utilization of the waste from pineapple canning by the production of alcohol, the juice from the peels was filtered, treated with lime to produce the citrate from which citric acid was recovered, by a process similar to that described in Chapter 24 (from waste lemons), and the filtrate from the lime-treated juice was decolorized with decolorizing carbon and concentrated to a sirup which was blended with sucrose sirup and used in the canning of pineapple. However, it was found that the canned pineapple gradually deteriorated in flavor between the time of canning and its sale to consumers. In 1930 the Dole Hawaiian Pineapple Company, Ltd. discontinued the production and use of such a sirup and instead blended cane-sugar sirup with the fresh, unconcentrated juice and used the blend in canning sliced pineapple.

In 1941, at the suggestion of James Dole, founder of the company, experiments were begun on the use of ion-exchange resins for purifying the

juice before its concentration to a sirup for use in canning. Laboratory and pilot-scale tests were successful. Ion-exchange resins are synthetic organic materials that have the ability to adsorb from solution ions of metallic bases and organic acids. The type that removes positive ions from solutions (the cations) are known as cation resins; those that remove acid ions are termed anion resins. The resins are made by several different manufacturers; those used in the Dole Hawaiian Pineapple Company, Ltd., plant are made by the Chemical Process Company of California.

As a result of the research mentioned above, a large sirup plant for utilizing the waste from pineapple canning was constructed at a cost of $750,000 and put into operation during the canning season of 1947 and has been in successful operation since then. It was designed to treat 300,000 gal. of juice per day and has recovered about 30 lb. of sugar equivalent from each ton of fresh pineapple canned in the company's cannery. More than 6,500,000 lb. of sugar in the form of sirup has been recovered each year and used in the canning of pineapple. Dr. George Felton was in charge of the research program for the cannery.

As described in a report by Felton (1949), the processes followed in recovering a sirup and citric acid from the peels and other waste is about as follows.

The fresh pineapple as received at the cannery is graded, washed, and fed to the Ginaca machine, which removes the "shell," or skin, and the core and trimmings in a single swift operation and delivers the cylinder of peeled and cored fruit to a slicer. The sliced fruit is sorted and trimmed, canned, siruped, vacuumized, sealed, and sterilized, as outlined in Chapter 8. The shells and other inedible waste are shredded and then pressed in a powerful helical-screw continuous press. The juice is heated in a continuous heat interchanger to 140 to 160°F., screened to remove coarse fiber and particles of pulp, heated to 190 to 200°F., to coagulate heat-coagulable proteins; mixed with the required amount of infusorial-earth filter aid; and filtered in a plate-and-frame filter press.

It is then treated with lime slurry at about 190°F. to precipitate much of the citric acid as the citrate and treated further with lime to bring the pH value of the juice to 5.3. Precipitation of the citrate is conducted at 190°F., and the citrate is separated from the juice by filter press. The filtrate is transferred to the ion-exchange department, and citric acid is recovered from the calcium citrate, as described in Chapter 24.

The hot, filtered juice is next cooled in a heat-interchanger unit in which much of the cooling is done by the incoming raw juice from the presses. The juice first goes to a tank 10 ft. in diameter and 10 ft. in height that is filled with Duolite cation-ion exchange resin C-3. The juice displaces the water in the resin, a procedure known as "sweetening on." As the juice flows through the cation-resin tank, most of the metallic ions such as cal-

cium, potassium, and sodium ions are adsorbed by the resin; thus the ingoing juice may have 1,500 p.p.m. of potassium ions and the treated juice less than 5 p.p.m. The juice is very acid in reaction after treatment with the cation resin, its pH being about 2.0. It then is passed through the first anion-resin tank in which most of the acid ions are adsorbed, and the juice emerges from it in the alkaline range at about pH 10. The juice is treated in a second cation-resin tank in which the pH value changes to 3.0 to 3.5. Only traces of K and Na remain. As an indication of the very low mineral content of the treated juice, its conductivity is low and its specific resistance to passage of an electric current is high, 5,000 to 20,000 ohms.

A second treatment with anion-exchange resin is given, resulting in a juice practically free of acid ions and very slightly alkaline in reaction. A small amount of juice from the second cation unit is added to bring the pH value to 8.0.

The coloring matter and other components of the juice that in the earlier sirups (prior to 1930) had caused deterioration in flavor of pineapple canned in it are removed in large degree by the cation resin and the remainder by the anion resin. The juice receives two cation- and two anion-resin treatments.

From the second anion-resin treatment it is pumped to a quadruple-effect, high-speed vacuum concentrating unit in which it is concentrated to 25 to 50° Brix. The resulting light sirup has a faint but recognizable pineapple flavor and a very light yellow color. It is pumped to the cannery, where cane sugar is added to adjust the Brix degree to the required level, or it is blended with simple sucrose sirup for use in canning sliced pineapple. Results have been very satisfactory, and there has been no deterioration in flavor of the pineapple due to use of the refined sirup.

After a certain period of use the resins must be regenerated; i.e., the adsorbed minerals and organic compounds must be removed. The cation resin is treated with sodium chloride brine to remove adsorbed calcium and is followed by back washing to remove residual brine. The resin is next treated with dilute NaOH solution to remove adsorbed coloring matter, etc., and is washed with warm water. It is then treated three times with 5 per cent sulfuric acid and rinsed with water until the acid is removed.

The anion resin is regenerated with 2 per cent NaOH solution and rinsed until free of the hydroxide. As there are five pairs of cation and anion tanks, operation of the ion-exchange treatments can be continuous; as one set of four tanks is being regenerated, another can be on stream (see Felton's paper for further details).

The ion-exchange-resin system of refining a fruit juice for conversion into a sirup for use in canning is applied industrially, in so far as the author is aware, only to pineapple juice; nevertheless, it could be utilized for the treatment of other juices and sugar-containing liquids, such as juice

expressed from sorghum cane, or grape juice, or a water extract of cull raisins. Such economic factors as cost and availability of the raw material, market or use for the finished product, and costs and returns would decide the practicability of the application of this process.

The press cake from pressing of the pineapple shell and other inedible waste is dried and used for stock feed. The commercial plant in which sirup is made from pineapple waste was designed by the Dorr Company of New York in cooperation with chemists and engineers of the Dole Hawaiian Pineapple Company, Ltd. Operations are controlled from a central panel. Valves in the lines that handle the juice and other liquids are, according to the report mentioned earlier, Saunders type with rubber diaphragm and are operated by air pistons controlled by solenoid pilot valves actuated by relays on the control panel. The panel also contains flow controllers, flow-rate indicators, conductivity meters, pH meters, a temperature recorder, density meter, and dials indicating the levels in all the regenerant tanks. The various switches and valves can also be operated manually when desired.

Fruit Pits. In the canning of peaches, apricots, and cherries, a large quantity of waste pits is obtained. These have been utilized in Germany and the United States for the manufacture of a fixed oil, bitter-almond oil, and macaroon paste.

Apricots, prunes, cherries, peaches, and almonds are botanically closely related, all being members of closely related genera of the Drupaceae family. The fixed oils and bitter-almond oil obtained from the kernels of these various fruits are practically identical in composition, the bitter principle in all cases being amygdalin.

Separation of Pits and Kernels. The kernels contain the most valuable constituents of fruit pits, and the first step in their utilization is the separation of the kernels from the shells. Apricot, bitter almond, cherry, and prune pits are easily crushed between heavy iron rollers so adjusted that the pits are broken and the kernels not crushed. The broken pits and kernels drop from the crusher into a tank of brine of such concentration that the kernels float and the shells sink.

The kernels are skimmed from the surface of the brine by a mechanical device and are sprayed with water to remove excess salt. They are then dried, cleaned by grain-cleaning machinery to remove shriveled kernels and other refuse, and sorted by hand on belts to remove pieces of shell, moldy kernels, and other objectionable material not removed by the cleaning machine.

Yields of Kernels. Apricot pits yield about 23 to 24 per cent of kernels, and peaches about 7 per cent. Peach pits are difficult to crack, and the kernels are difficult to recover, a large percentage of the kernels being poorly developed or dried and devoid of oil. Cherry pits, according to

Rabak, yield about 28 per cent of kernels. Prune pits yielded about 10 to 15 per cent of kernels in laboratory tests made at the University of California.

Expressing the Fixed Oil. The fixed oil is the most valuable constituent of these waste pits. It is generally recovered by pressure but may also be extracted by the use of volatile solvents. If solvents are used, the resulting oil, unless heavily refined, is usually fit only for soap stock.

The kernels are coarsely ground to facilitate pressing, heated to near the temperature of boiling water by steam or by passage through a steam-jacketed tube, and pressed by a continuous press known as an "expeller" or by a press in which cloths and racks are used as in the pressing of olives.

The continuous press is inexpensive to operate but gives a cloudier oil and lower yield than pressing between cloths and racks; nevertheless it is the one generally used in expressing oil from seeds. It consists of a horizontal perforated, heavy, metal, steam-jacketed cylinder fitted with a screw conveyer. The kernels enter the press through a hopper at one end of the cylinder and are conveyed by means of the screw toward the opposite end of the cylinder and over a heavy metal cone projecting into the cylinder. As the diameter of the cone increases, the pressure applied to the kernels increases. The pressure can be adjusted by decreasing or increasing the size of the outlet and the distance between the walls of the cylinder and the cone. The press may be heated by a steam jacket. The press cake passes out over the cone, and the oil flows through perforations in the floor of the press cylinder. The press cake is ground and pressed a second time to recover as much of the oil as possible.

Use of Hydraulic Presses. In using hydraulic presses kernels are prepared as for pressure in the expeller; the heated, ground kernels are packed in heavy press cloths usually made of camel's hair; steel plates are placed between each pair of cloths; and a pressure of 3 to 5 tons per sq. in. is applied. The press cake should be reground and pressed a second time.

Yields. From apricot kernels a yield of at least 33 per cent of oil should be obtained, from peaches about 25 per cent, and from cherries and prunes about 30 per cent.

Refining the Fixed Oil. The oil contains considerable solid material, such as particles of kernels and kernel skins. These can be removed by screening or coarse filtration.

The raw oil is often high in free fatty acid, dark in color, and rancid in flavor, and it is necessary to refine it. This can be done by treatment with a small amount of sodium carbonate to neutralize the free acid, by the addition of a decolorizing agent such as vegetable decolorizing carbon or fuller's earth, and by heating with steam *in vacuo* to volatilize objectionable odors.

Titration of the acidity and laboratory trials with small measured volumes of the crude oil will determine the quantities of sodium carbonate and decolorizing carbon or fuller's earth that must be used. Usually 2 to 3 per

cent of powdered bone black or finely ground vegetable-decolorizing charcoal will be sufficient. The oil is generally not bleached water-white but is usually decolorized only to a light straw color.

The reaction between the fatty acid and the carbonate is facilitated by the presence of about 0.5 per cent of water, and heat is necessary for the best results. In one factory in California, which is no longer in operation, the mixture of bone black, sodium carbonate, oil, and about 0.5 per cent water was heated to about 190 to 200°F. The mixture was then mechanically agitated, and a stream of carbon dioxide was passed through the oil to remove objectionable odors by volatilization. After several hours' treatment the oil was allowed to settle and was filtered. The finished oil was nearly colorless and was of pleasing flavor and odor. The oil can be deodorized, also, by passage of steam through the oil held under vacuum.

The refined oil finds a market for use in the preparation of face creams and pharmaceuticals but is also an excellent table oil and at one time was used extensively in California in the canning of sardines. At present most of the oil is shipped out of the state to New York and elsewhere for refining. The former German market is not active (1957).

Composition of the Fixed Oil. The fixed oils from apricots, sweet almonds, bitter almonds, peach kernels, prune kernels, and cherry kernels are practically identical in composition. The principal compound present in these oils is olein, $C_3H_5(C_{17}H_{33}CO_2)_3$. There are also present small amounts of stearin and palmitin, both of which are solid fats.

Bitter-almond Oil from Press Cake. The press cake remaining from the extraction of the sweet oil contains the bitter principle, amygdalin, and an enzyme, emulsin, which has the power of converting amygdalin into benzaldehyde, glucose, and hydrocyanic acid, according to the following reaction:

$$C_{20}H_{27}O_{11}N + 2H_2O = C_6H_5CH{:}O + HCN + 2C_6H_{12}O_6$$

Benzaldehyde imparts the characteristic odor and flavor to bitter-almond oil and to flavoring extracts such as "wild cherry." Artificial bitter-almond oil and flavoring extracts are commonly made from benzaldehyde synthesized from benzene, a coal-tar product, and a bitter-almond oil from fruit kernels is sometimes adulterated with the synthetic benzaldehyde.

Hydrolysis of Amygdalin. The press cake is heated with about 12 volumes of water to soften the ground kernels and to extract the amygdalin. The heating of the ground kernels before pressing may destroy most of the enzyme emulsin, making it necessary to add to the mixture of water and kernels freshly ground unheated kernels equal to about 10 per cent of the press cake, in order to hydrolyze the amygdalin. The mixture is warmed to a temperature of about 50°C. (122°F.) for an hour or less. Hydrolysis can

also be conducted at room temperature, but at least 12 hr. should be allowed at this temperature.

If the kernels are not heated to a high enough temperature before pressing to destroy the enzyme emulsin, the press cake does not require the addition of unheated kernels to cause hydrolysis of the amygdalin. This method has been used successfully in one California oil factory.

Distillation. Benzaldehyde boils at 179°C., and in order to separate it from the water and kernels, it is necessary to distill it from the mixture with a current of steam, which is done by placing the mixture of kernels, water, etc., in an enclosed metal tank, passing a current of steam through the mixture, and condensing the vapors by a water-cooled condenser. There should not be any open outlets from the distillation apparatus within the distillation room, because of danger of poisoning from the hydrocyanic acid that distills with the water and benzaldehyde. The bitter-almond oil settles to the bottom of the vessel in which the distillate is collected and can be easily separated from the water that distills with it. It contains from 2 to 4 per cent of prussic acid, and if the oil is to be used for medicinal purposes, the prussic acid is not removed.

Refining. If the bitter-almond oil is to be used as a flavoring material, most of the prussic acid must be removed. This can be done by heating with slaked lime and an iron salt or by treating with sodium bisulfite. It is necessary to redistill the benzaldehyde from the reaction mixture.

Rabak (1908) obtained from peach kernels 0.7 per cent of bitter-almond oil; from apricot kernels 1.6 to 0.8 per cent; from prune kernels 0.3 to 0.46 per cent; and from cherry-kernel press cake 0.95 per cent. The yield from the press cake is nearly 50 per cent greater than from the fresh kernels, owing to concentration of amygdalin in the cake, by expression of oil.

Debittered Kernels and Macaroon Paste. Macaroon paste is used extensively by bakers. Although most macaroon paste is made from sweet almonds, this product could be prepared from apricot kernels.

In one method of preparing macaroon paste, the kernels are first blanched, i.e., heated in water a short time to soften and loosen the skins, and are then peeled mechanically. The temperature used should be such that the emulsin is not injured, viz., not above 140°F. The peeled kernels are ground and heated with water at about 50°C. to cause hydrolysis of the amygdalin. The resulting benzaldehyde and prussic acid are removed by steam distillation, and the residual meal is separated from the excess water by treatment in a filter press. It can then be mixed with sucrose and heated in a steam-jacketed kettle to remove excess water.

In experiments conducted by the author in 1942 the apricot kernels were heated in water at 135 to 140°F. for a few minutes to loosen the skins and were then peeled by hand. They were divided into six lots, which were then

heated in water at 120, 130, 140, 150, 155, and 160°F., and disappearance of the bitterness was observed by tasting. When they had become free of the bitter taste they were dehydrated in a small air-blast dehydrater at 150°F. It was found nearly impossible to destroy all the amygdalin at 120 to 130°F. before discoloration of the kernels occurred. At 140°F. the rate of hydrolysis of the bitter principle was rapid; 150 and 160°F. appeared to be above the optimum for the naturally occurring amygdalase enzyme. The debittered kernels may be used in place of sweet almonds in cookies, cakes, and other bakery products.

When the kernels were heated in running water at 140°F. for 24 hr. the amygdalin had been completely hydrolyzed and the HCN had been leached from the kernels. Soaking the kernels in 1 to 1½ per cent sodium hydroxide solution until it had penetrated the kernels completely followed by soaking in repeated changes of cold water as in olive pickling removed the amygdalin and gave a product free of bitterness. After dehydration it was found suitable for use in making a paste with sugar or for use in baked products or candy.

Press-cake Meal. The press cake, after grinding and distillation with steam for recovery of the bitter-almond oil, can be separated by pressing from the water with which it is associated and used for a stock food, high in protein and carbohydrates. Rabak (1916) found cherry-kernel press cake to contain 30.87 per cent protein, 42.13 per cent nitrogen-free extract, 8.9 per cent crude fiber, and 13.1 per cent ether extract. It was richer in protein than coconut meal but contained less protein than did cottonseed meal. Analyses of apricot-, peach-, and prune-kernel meals are not given, but these are probably of approximately the same composition as cherry-pit meal.

The solution left in the still after distillation, according to Rabak, contains approximately 6 per cent by weight of the original press cake, which can be evaporated to dryness and incorporated with the dried and ground press cake.

Charcoal from Pits. Several factories in the past have made a carbon or charcoal from waste peach pits and waste shells from the cracking of apricot pits. Originally the pits were dry-distilled in a large steel retort held at high temperature over a furnace. The distillate containing the vapors of acetic acid, acetone, and methyl alcohol was condensed. A tar rich in creosote was also recovered as a distillate. In later plants the products of distillation were returned continuously to the furnace and burned with the principal fuel, usually natural gas or crude oil. The carbon was used to some extent in chicken feeds and for the casehardening of steel. At present it is used chiefly in the making of briquettes for use in barbecue pits for the cooking of steaks and other meats. In making this product charcoal in one plant is made into a powder, then mixed with a small amount of a special corn-product binder

and a little water added by spray. The moist mix is compressed into briquettes in a continuous rotary press, and the briquettes dried to very low moisture content on trays in an air-blast tunnel-type dehydrater.

Waste from Grape-juice Factories and Wineries. In the preparation of grape juice and wine, grape stems and grape pomace are obtained as waste products. The pomace consists of the pressed skins and seeds.

Stems. Grape stems, separated from the grapes at the time of crushing, normally constitute approximately 5 per cent of the original weight of the grapes. Rabak and Shrader find that the Concord grape stems yield about 2 per cent of cream of tartar when chopped in short lengths or ground and extracted with boiling water. The watery extract is concentrated by boiling and allowed to cool and stand 24 hr. or longer. Cream of tartar (potassium acid tartrate) separates as crude crystals that can be purified by redissolving in water and recrystallizing. The watery extract was too low in tannin to warrant concentration. Tartrates, including free tartaric acid, can be recovered by treatment of a hot-water infusion of the stems with calcium carbonate and calcium hydroxide, according to Marsh (1944).

Separating Seeds and Skins. The pomace consists of seeds and skins which must be separated before the seeds are used for oil. Rabak and Shrader found that the separation could be made fairly satisfactorily by screening out the seeds after passing the wet pomace through a pomace picker, such as is used in the vinegar industry, and through an apple grater to break up the press cake thoroughly. The seeds fall through a ¼-in. screen, and the skins are retained.

If the pomace is dried thoroughly before screening, an almost perfect separation of the skins and seeds can be made by screening and fanning.

Drying can be economically accomplished in rotating cylinders heated by a blast of air or steam pipes.

Recovery of Tartrates. Pomace may be extracted with water. The extract is filtered or fined with bentonite or merely allowed to settle overnight. Based on analysis, calculated amounts of calcium hydroxide and calcium chloride are added in the ratio specified by Marsh (1944) which varies somewhat with the pH and tartrate content. Optimum pH is about 4.5. After stirring and settling, the supernatant liquid is discarded and the calcium tartrate sludge is washed and dried. Cream of tartar factories convert the calcium tartrate to tartaric acid by addition of dilute H_2SO_4, filtering off the $CaSO_4$ and concentrating and crystallizing the tartaric acid. For details see Marsh (1944).

Recovery of Oil. In France the seeds are ground and the oil is extracted by means of an expeller, as described for the extraction of oil from fruit kernels, and a yield of 10 to 15 per cent is reported. More satisfactory results are obtained if the seeds are decorticated (hulled) before pressing. This is accomplished by crushing the seeds lightly between rolls and by

screening and fanning to remove the hulls. The kernels may be ground and pressed or pressed direct without grinding. If decortication is not accomplished, the hulls cause excessive wear on the expeller and a high percentage of crude fiber in the press cake, which greatly impairs its value as a stock food.

In a California grape-seed by-products factory the ground seeds are pressed hot in hydraulic presses between heavy cloths and steel plates. In another the dried seeds from wine-grape pomace are ground and extracted with low-boiling gasoline and the solvent is removed by distillation. The oil is sold for soap stock or refined by steam treatment under vacuum, neutralization with sodium hydroxide, and decolorizing with carbon for use as a food oil.

In Europe the oil in some factories is recovered by extraction with a volatile solvent, such as benzene, gasoline, trichloroethylene, or carbon bisulfide, but it is difficult to remove all trace of the solvent from the oil, and it is generally only suitable for soap making. However, by severe refining an edible oil can be prepared. Extraction with solvents is conducted in tall steel tanks, a battery of several tanks in series being used. The residue from solvent extraction with gasoline or benzene is usually not suitable for stock food and can be utilized only as a fertilizer, whereas the press cake from an expeller or hydraulic press can be used to good advantage as a stock food. Residues extracted by trichloroethylene can be made suitable for stock food.

Tannin from Hulls. The hulls from the decortication of grape seeds contain a large percentage of tannin, which can be extracted by boiling with water and concentrated to a heavy sirup. Rabak and Shrader have found such a product suitable for the tanning of hides. A yield of 10 per cent of sirup containing 15.5 per cent of tannin was obtained from the hulls.

Jelly from Grape Skins. Skins from Concord grapes, and the whole grape pomace as well, were found suitable for the preparation of jelly and jelly stock, by the usual methods described in Chapter 14. An average of 24 oz. of jelly was obtained from each pound of pomace. California wine-grape pomace is not suitable for this use.

Character of Grape-seed Oil. Grape-seed oil is a semidrying oil, resembling soybean oil in this respect, and on this account can be used in paints. If to be used as a table oil, it must be refined by treatment with sodium carbonate or other alkaline material, to remove free fatty acids, and with decolorizing carbon or fuller's earth, to remove excess color.

Value of Press Cake. The press cake from grape-seed-oil production is suitable for stock food, although it is desirable to mix with it bran or alfalfa meal or similar material to reduce the tannin and crude-fiber content of the mixture at the time of feeding. The press cake is very high in crude fiber,

an objectionable feature from the standpoint of its value as stock food. According to Rabak and Shrader, press cake from the decorticated seeds in their experiments contained 4.48 per cent fat, 14 per cent protein, 29.7 per cent nitrogen-free extract (starch, etc.), and 43.2 per cent crude fiber, thus comparing favorably, except in crude fiber, with other seed meals in feeding value.

Use of Pomace for Stock Food. The pomaces from grape-juice production, wine making, apple-juice production, and olive-oil making may be dried and used for stock food.

In California grape pomace from wineries and apple pomace from vinegar factories are now being dried in direct-fired rotary-drum driers. It is then ground in hammer mills and used in the feeding of livestock, particularly dairy cows. The fuel used for heating the air in drying in most cases is natural gas. In one form of dehydrater the flames and heated air from the furnace enter the drying drum with the incoming wet pomace, the temperature being about 1300°F. The dried pomace and spent air (at about 300°F.) are drawn from the lower, opposite end of the drum. The drum in this case is about 60 ft. long and about 6 ft. in diameter. In another type of drum drier used for grape pomace a metal cylinder extends through the center of the main drying drum. The flame and hot gases enter this inner cylinder, pass through it to the opposite end, and are returned through the space between the two cylinders to the furnace end of the drier. This type of drier permits longer contact with the drying medium without danger of scorching the product, thus giving sufficient time for the moisture in the seeds and larger lumps of pomace to diffuse to the surface.

The pomace must be dried to less than 10 per cent moisture in order to prevent spoilage by molding and spontaneous heating. One large dairy in California is successfully using 30 per cent of the finely ground dry pomace in the cows' ration, although 15 to 20 per cent is the more common proportion.

The pomace is high in crude fiber. Its principal value is its moderate content of oil and protein. Most of the feeding value lies in the kernels or meaty portion of the seeds, as the skins, stems, and seed hulls have little digestible substance and are of value only for roughage. The average composition of five samples of the dried ground pomace from five large California wineries was as follows: ash, 5.99 per cent; crude fat extract, 5.33 per cent; protein, 11.9 per cent; crude fiber, 35.9 per cent; and moisture, 3.44 per cent. The moisture content is lower than that of the pomace as fed because the samples were taken direct from the drier and sealed in jars; in practice the dried, ground pomace is stored in bags or bins and absorbs considerable moisture from the air. Pomace from dry-wine making has greater feeding value than that from sweet-wine making as it contains some

sugar and other soluble food values, whereas the pomace from sweet-wine making is thoroughly leached with water several times to recover residual alcohol for production of brandy used in fortification.

Apple pomace is handled in a similar manner by drying and grinding as described for grape pomace. It is of lower protein and fat content than grape pomace but is rich in carbohydrates. Therefore it is a good supplement to the latter.

Olive pomace contains a large proportion of seeds, which must be removed or finely ground before the pomace may be used as a stock food. The seeds may be removed by drying the pomace, breaking it into individual seeds and particles of pulp, and screening in a blast of air. The seeds are valuable for fuel, and the pulp and skins may be used for stock food. The pulp is rich in oil.

Almond Hulls. Almonds constitute one of California's most important tree crops, the annual production being about 35,000 to 40,000 tons in normal years; late frosts occasionally damage the crop and lower production. On the tree the nuts develop a rather thick outer hull which corresponds to the fleshy portion of a peach. As the nuts ripen the hulls burst open, partially dry, and loosen from the nuts. The nuts with hulls loosely attached are knocked from the trees, and the hulls removed by machine. The nuts are dried and sent to a packing plant; the hulls collect in piles and are usually allowed to dry in the sun. It is estimated that for each ton of hulled nuts there is produced about 1 ton of air-dried hulls. Until 1950 most of the hulls were allowed to go to waste, except in the Paso Robles area in central California where most of the hulls were spread in the sun, dried, and fed in combination with cottonseed meal and alfalfa to livestock.

On the basis of studies conducted during 1945 to 1947, Cruess, Kilbuck, and Hahl reported the following data. Air-dried hulls from several almond-producing districts averaged about 6.5 per cent moisture content, 25.61 per cent total sugar, 12.6 per cent crude fiber, 1.20 per cent ether extract, 8 per cent hemicellulose, 2.4 per cent pectin, 4.38 per cent tannin, 1.63 per cent starch, about 3.25 per cent protein, and 4.60 to 6.27 per cent total ash, most of which was water-soluble and high in potassium.

Some of the hulls were made into ensilage by filling a barrel with the dry hulls, adding water to cover, heading up the barrel, and allowing to stand several weeks. Liquid expressed from the fermented hulls contained 3.48 per cent alcohol, 0.86 per cent acid as lactic, 0.27 per cent volatile acid, and 8.26 per cent soluble solids. It was of clean odor and taste. It was fed to sheep with oat hay with excellent results. Sheep readily eat either the air-dried hulls or the ensilage. For use of either cattle or sheep the air-dried hulls should be moistened with water and allowed to stand several hours to soften them. Later the Animal Husbandry Department of the University of California (Professor Miller) made exhaustive and successful

feeding trials with sheep. By 1951 their use for part of a mixed ration for sheep and cattle had become very general. At present some of the hulls are fed dry; others are converted into ensilage in pit silos with good results.

In our experiments ground hulls were extracted with water and the extract adjusted to 1 per cent tannin content. With the assistance of the chemist of a nearby tannery, several pieces of limed, dehaired, raw cowhide were tanned in this solution with excellent results; a 2 per cent tannin solution from almond hulls was less satisfactory, probably because the osmotic pressure of the solution was too high because of presence of other water-soluble substances, chiefly sugars. Probably an alcohol extract would contain less nontannins.

A refined sirup of pleasing flavor was prepared by decolorizing a water extract of the hulls with decolorizing carbon, filtering with infusorial earth, and concentrating under vacuum.

Brandy and alcohol were made in small amounts by grinding the dry hulls, adding about three times their weight of water, fermenting with pure wine yeast, and distilling. The yield was 16.8 per cent of alcohol (cubic centimeters of alcohol per 100 grams of air-dried hulls). A neutral alcohol for use in medicinal preparations or in gin or a high-proof alcohol for fortification of various alcoholic drinks could be made from the hulls. A water extract of the hulls proved suitable as a culture medium for the growth of a feed yeast, *Torula utilis*.

However, after "all is said and done," the air-dried hulls in their natural state or converted into ensilage for use in a mixed ration for livestock appears to be the most practicable method at present.

Raisin Seeds. In the packing of Muscat raisins in California the waste seeds constitute about 8 to 12 per cent of the original weight of the raisins, or a total of about 5,000 tons annually. Adhering to the seeds is a considerable amount of pulp and sirup, which contains sugar equal to about 20 per cent of the weight of the seeds, and the seeds contain oil and tannin, both valuable constituents.

The freshly separated seeds soon develop fermentation and become moldy if allowed to stand. It is therefore necessary to treat them at once if the sugar is to be recovered or utilized.

The seeds may be washed with warm water to dissolve the sugar from the adhering pulp and sirup. The solution, which contains sugar and other grape solids, can then be filtered and concentrated in a vacuum pan to a sirup of the desired density for table use, baking, etc. At present it is used for production of brandy.

The sugary extract from the seeds can be fermented with yeast and distilled to obtain ethyl alcohol or brandy. This is being done at present in a by-products factory in Fresno, California, and the resulting brandy is used by various wineries in fortifying sweet wines. A simplified procedure

consists in fermenting a mixture of water and unwashed seeds, draining off the fermented liquid for distilling, and drying the residual seeds.

The alcoholic distillate may be diluted to about 10 per cent alcohol and acetified in vinegar generators to give a distilled vinegar of good quality, suitable for preservation of pickles or for table use.

The washed seeds are dried in a rotary drier in a blast of hot air and crushed and pressed hot in hydraulic presses, although expellers could be used to good advantage. The yield of oil, its chemical composition, and its general qualities are very similar to those noted previously for oil from grape seeds obtained from pomace from grape-juice factories and wineries. At present the oil is sold for industrial purposes, e.g., soap making, paints, etc., and is also used, after partial hydrogenation, for coating seeded raisins to prevent stickiness.

When properly refined, raisin-seed oil can be made into a very palatable table oil.

Some of the press cake is sold for stock food but is very high in crude fiber and should be mixed with other feeds before use.

Raisin Stems. Waste stems from California raisins have been utilized for fertilizer, their principal fertilizing ingredient being potassium. They are dried, ground, and applied to the soil with or without the addition of other substances. A total of approximately 7,800 tons of stems is available in California annually.

The stems may be utilized for recovery of cream of tartar and tannin. They are usually ground for use in mixed stock foods.

Utilization of Surplus and Cull Fruits. The utilization of surplus and cull fruits presents a much more important and difficult problem than the utilization of waste pits, pomace, seeds, and other waste products from factory operations. It is estimated that the surplus and cull fresh peaches not utilized in California in some seasons amount to about 100,000 tons annually. The quantity of cull apples at present not utilized is very large; no estimate is available. Large tonnages of surplus and cull dried prunes, fresh Bartlett pears, and plums are not utilized.

Such fruit can be utilized in preparing fruit jams, dried products, juices, wines, brandies, vinegar, denatured alcohol, stock foods, etc. Most of these products are discussed in other chapters, to which the reader is referred. The other products will be discussed briefly.

At present so-called "power alcohol," ethyl alcohol, for admixture with gasoline for use in gasoline motors, is in the public eye. On first thought this outlet appears attractive, but the production of alcohol from surplus fruits for this purpose will not bear analysis. For example, gasoline costs wholesale f.o.b. refinery about 5 cents a gallon; denatured alcohol from the cheapest raw material (molasses) costs not less than 25 cents a gallon. It would cost at least 35 cents a gallon if made from waste fruit, if the operator were to recover his operating costs. Alcohol can be made very cheaply from the

ethylene from cracked petroleum. Therefore, if gasoline producers were forced by law to add alcohol to gasoline, they would probably make it from petroleum. Gasoline-alcohol blends require special carburetion and engine adjustment. Furthermore, in moist weather they may absorb water rapidly and separate into a layer of water alcohol and one of gasoline. A ton of cull peaches would yield at most 10 gal. of absolute alcohol (only absolute, water-free alcohol can be used in gasoline). This would be worth wholesale, at a price competitive with gasoline, 5 cents a gallon, only 50 cents; or at the industrial alcohol price, 25 cents a gallon, $2.50. The cost of picking and delivery of the fruit is not less than $2 a ton and of manufacture not less than 15 cents a gallon of alcohol, or $1.50 a ton of fruit. On either basis the operator would lose money. Prices are considerably higher at present, but production of power alcohol from waste fruit would still be unprofitable unless subsidized.

For brandy production the possibilities are more attractive. A ton of peaches or pears would yield about 20 gal. of brandy of 100 proof (50 per cent alcohol). After aging and payment of the Federal tax of $9 per 100-proof gallon, it is likely the brandy could be sold at a profit if properly aged and introduced by adequate advertising. The procedure of manufacture consists in crushing, fermenting with pure yeast in the presence of about 100 p.p.m. of sulfur dioxide, and distilling in a pot still (batch or discontinuous still); or in grinding the fruit to a fine purée in a hammer mill, fermenting as above, and distilling in a continuous still as is done in making whisky or wine brandy. In any case construction and operation of a fruit-brandy plant require that the operator secure the necessary state and Federal permits and conform to the many stringent Federal regulations. Details may be secured from the Alcohol Tax Unit of the Internal Revenue Service and from the Federal Alcohol Control Administration.

Cull and surplus apples, grapes, oranges, and other juicy fruits suitable for brandy making are crushed, fermented, and pressed as in making red grape wine. The pomace may be leached with water to recover residual alcohol. Pure yeast and sulfur dioxide should be used to secure efficient fermentation. At present some cull fruit and fruit wastes from canneries are fermented and distilled to give high-proof neutral spirits of about 97 per cent alcohol, i.e., about 194 proof, for use in making cordials and liqueurs.

Cull dried fruits are mixed with about four volumes of water, fermented with pure yeast in the presence of sulfur dioxide, drained, and extracted with water. The first drained liquid is distilled; the water extract is added to the next lot of dried fruit. The residual fruit is dumped, although it could be pressed, dried, and ground for stock food. Dried fruits after fermentation are also ground to a fine purée in a hammer mill and distilled in a continuous still.

Fruits in dried form can be used successfully in breakfast cereals by

combining them in a thick dough made of whole-wheat flour or corn meal, flaking, cooking, and drying. Prune cereal made in this manner is palatable and has a mild laxative action. See later section in this chapter.

Fruits can be used in many bakery products to a greater extent than at present. This is particularly true of dried fruits. Bread containing 20 to 30 per cent of chopped dried-prune meat is an example of such products.

Fruits can be used very successfully to a much greater extent than at present in low-priced carbonated fruit beverages. Dried prunes yield a very palatable, mildly laxative canned or bottled juice that should have great commercial possibilities if carbonated (see Chapter 12 for details of producing carbonated beverages, canned prune juice, and other fruit beverages).

All such specialities, however, require for commercial success that the project be generously financed for a period of several years, because successful introduction of new food products requires much costly advertising and sales promotion. Disregard of this basic fact has been the cause of many failures in such ventures.

The utilization of cull citrus fruits is presented in Chapter 24.

Recently a national organization, supplemented by similar state organizations and known as the National Farm Chemurgic Council, has come into existence. Its national headquarters is in Detroit. Its purpose is to promote the utilization of farm wastes and farm surpluses for nonfood purposes and, as well, the production of new crops for such purposes. Examples of such projects are the growing of slash pine in the South for use in paper pulp, utilization of soybeans for plastics and soap-making, greater production of flax for fiber and paint oil, pressed fuel "logs" made of waste wheat straw, and the conversion of carbohydrate wastes into butyl alcohol and acetone by suitable bacterial fermentation and distillation. Still more recently the Federal government has appropriated funds for four regional by-products laboratories in the United States for research on utilization of surplus crops, including surplus fruits and vegetables.

Raisin Sirup. In experiments conducted at the University of California under the author's direction by Musco, Yanase, and Lee (1954), a satisfactory procedure for making a colorless and stable sirup from cull raisins was devised. Previous attempts to make such a sirup experimentally and commercially had not been successful because sirups decolorized with carbon soon darkened badly on storage, eventually becoming black, much as do dried fruits (Chapter 20). Also, if concentrated beyond 68° Brix, they become semisolid from separation of crystals of dextrose; the sugars in Vinifera grapes and raisins are levulose and dextrose, present in about equal proportions. At 68 to 72° Brix grape sirups and raisin sirups are liable to ferment.

The investigators mentioned above found that by the use of cation- and anion-exchange resins such as described earlier in this chapter in the section

on production of sirup for pineapple canning from waste pineapple shells and other inedible wastes from pineapple canneries, it was possible to make a raisin sirup that remained colorless in storage at room temperature (still colorless after 3 years' storage). The resins were furnished by the Rohm and Haas Company of Philadelphia (Amberlite resins) and by the Chemical Process Company of California (Duolite resins). Both types of resins proved satisfactory. The preferred procedure consisted in extracting the cull raisins in a battery of four extraction vessels at 140°F., using water in the first unit and extracts from the preceding vessels in each of the following extractions. The water extract of about 20° Brix was filtered, treated with the cation resin, and then with the anion resin. The resulting deionized juice was slightly alkaline; enough citric acid was added to render it slightly acid, and it was then concentrated *in vacuo* at low temperature (not above 120°F.) to 68° Brix for use as a table sirup. It was then flash-heated to 150°F. to kill yeasts and canned or bottled hot (145 to 150°F.). It was immediately cooled in water to room temperature. It is practically a pure invert sirup. For use in baking and candy making it was concentrated to 75 to 80° Brix, in which range it is not necessary to pasteurize it. It was found satisfactory for blending with sucrose sirups for the canning of fresh fruits. Grapes cannot be grown to compete in price with sugar beets and sugar cane. On the other hand, it is probable that low-cost cull raisins could be used profitably for the production of a colorless sirup by the procedure described above.

Fruits in Cereals. As first proven by Reed (1929) and demonstrated later by Cruess and Irish, it is feasible to combine dried fruits with various cereal products to produce satisfactory breakfast cereals rich in fruit. Recently Musco and Cruess (1953) have improved upon the earlier formulas. One of the most satisfactory procedures was the following:

	Parts by weight
Bran	45
Kreata, a wheat product	15
Salt	3
Baking powder	1–2
Dried fruit, ground	35
Water	25

The bran, Kreata, salt, baking powder, and water were combined to give a heavy dough which was kneaded until smooth. The dough was then cooked in an autoclave at 240°F. for 60 min. The dried fruit was finely ground and mixed with the cooked dough to give a smooth mixture. The mixture was then extruded through fine openings in a circular plate of a small laboratory press to give a vermicellilike product. This was dehydrated to bone dryness and broken mechanically into short lengths to give a shredded breakfast cereal; or the dough was extruded as a thin ribbon which was cut into short

lengths by a knife attached to the press. These "flakes" were then dehydrated and lightly toasted in an oven to give a light brown flaked cereal. The baking powder was replaced in some experiments with ammonium carbonate as a leavening agent, and it proved satisfactory.

Another satisfactory formula was the following:

	Parts by weight
Bran	50
Dried fruit, ground	47
Salt	3
Water	40

Combine all ingredients and knead into a stiff dough. Form into shreds or flakes as previously described, dehydrate, and toast lightly.

The fruit-containing dough from either of the two formulas may be formed into pellets about the size of large kernels of corn, dried to about 16 per cent moisture, and rolled into flakes in a corn-flaking roll-type machine.

Fruit Candies. Raisins and chopped or coarsely ground dried fruits have been used in various candies successfully in experiments conducted at the University of California in the Food Technology Department over the past twenty-five years or longer (see references). The latest paper on this subject is by Binder (1954). He used raisins in his experiments, but these may be replaced with chopped dried figs, apricots, apples, or other dried fruits. Only two formulas will be given here; others may be obtained from several of the references listed at the end of this chapter.

The first formula is one for a dried-fruit frappé fondant:

Drivert (a powdered, dry fondant mix)	32 lb.
Invert sirup (such as "nulomolene")	1 lb. 7 oz.
Water	1 lb. 7 oz.
Vanilla extract	To suit
Confectioners' fat, melting at 98°F.	16 lb.
Frappé (see below for method of making)	14 lb.
Lecithin, for confectioners' use	2½ oz.
Midget-size raisins or chopped dried fruit	42 lb.
Walnut meats	12 lb.

Mix the Drivert, water, invert sirup, and vanilla and heat to 160°F. Add the frappé and lecithin and whip until homogeneous. Mix in the raisins or chopped dried fruit slowly in order not to tear the fruit unduly. Pour onto an oiled slab or waxed paper and allow to harden. Cut in pieces of desired size and shape. Coat with milk chocolate in the usual way.

The ingredients for frappé are sugar 25 lb., corn sirup 30 lb. 10 oz., invert sirup (nulomolene) 30 lb. 10 oz., albumen 2½ lb., water 16½ lb.

Mix the albumen with 11 lb. of the water and allow to stand until the albumen is well soaked. Cook the invert sirup, sugar, and 5½ lb. of water to 247°F. Let cool to 240°F. In a mechanical mixer place the albumen solution

and mix slowly until homogeneous. Then increase the speed and add the hot sirup slowly. Beat to maximum volume. Allow to cool before using.

A jelly candy with dried fruit was made as follows:

Sugar, cane or beet	15 lb.
Corn sirup, confectioners' heavy	15 lb.
Water	18 lb.
Citrus pectin, No. 451 (150 grade, slow-set)	13 oz.
Whole raisins or chopped dried fruit	18 lb.
Citric acid	2¾ oz.
Sodium citrate	1¼ oz.

Mix the dry sugar and dry pectin well. Dissolve the sodium citrate and one-half of the citric acid in 8 oz. of water. Dissolve remainder of citric acid in 3 oz. of water. Heat the corn sirup and remaining water to boiling. Add the dry sugar and pectin mixture to boiling sirup slowly with stirring. Continue boiling to 224°F. Add the citric-acid–sodium-citrate solution and the citric-acid solution and reboil to 224°F. Remove from the heat and stir in the raisins or chopped fruit evenly. Spread on an oiled slab or oiled paper to "jell" and cool. Cut in pieces of desired shape and size. Roll pieces in coarse sugar. Place on trays and allow to dry at room temperature several days before packing.

Many other fruit candies have been made, such as jelly candy made with fruit juice or fruit purée, dried-fruit caramel, dried-fruit divinity and chocolate fudges, brittles, coconut bars with dried fruit, marshmallow containing fruit, uncooked dried-fruit candies, and others. (See references. See also Chapter 15, the section on fruit candies.)

Other Products. In cooperation with the Dairy Industry Department of the University of California various new and satisfactory formulas for the use of fruits in ice cream, sherbet, and ices have been developed by the Food Technology Department of this university (see references).

In addition, various other food products have been prepared from small or slightly blemished fresh fruits unsuitable for fresh sale or for canning in usual forms. These include canned-fruit purées, for use in the home in puddings, whips, etc., and commercially in ice cream, jams, etc.; fruit-jelly stocks for homemade jellies, by boiling the crushed fruit with water; pressing, filtering, adding sufficient citrus or apple pectin to give a "sure-fire" jelly base, and preserving it by canning or bottling; julienne-strip clingstone peaches or pears in light sirup to utilize fruit too small for canning in halved form; canned sieved peaches or pears in light sirup to utilize fruit too small for canning in halved form; canned peaches or pears in the form of a "crush" similar to crushed pineapple; various fruits canned in a light sirup thickened with special cornstarch and designed for use in the home for making pies; canned baked pears; "fruit granules" made by mixing dextrose sugar such as "cerelose" with dried fruit, heating to blend

well, dehydrating to bone dryness, crushing and screening to give a granular product for use in candies, cake fillings, frostings, etc.; vacuum-dried fruits ground to a powder; and several forms of ice-cream bases for home use. In the chapter on packing of dried fruits was given the procedure used by the Vacu-Dry Company for the preparation of puffed dried fruits in pieces of medium size by special vacuum-drying procedure, the pieces being known as "nuggets." Powdered fruit juices are made by a procedure devised by the U.S.D.A. Western Regional Research Laboratory, Albany, California; a special vacuum-drying technique is used.

Extensive investigations by Strachan et al. at the Agricultural Experiment Station in Summerland, British Columbia, Canada, have resulted in the development of procedures for preparing and canning fresh fruits for use in making pie in the home (see reference; also Chapter 8).

Available space in this book does not permit presentation of the procedures used in making and preserving the foregoing products, but details will be found in the references given at the end of this chapter.

Waste Juices from Canning. In pitting sour cherries a large amount of juice accumulates and is generally not utilized. Rabak (1916) estimates the juice so obtained at 70 gal. per ton of fresh cherries. It could be collected, heated, filtered, and added to the sirups used in canning cherries.

The juice is also suitable for the manufacture of vinegar, brandy, or denatured alcohol, or, when partially neutralized with calcium carbonate and concentrated *in vacuo*, it yields a palatable table sirup. It may also be combined with pectin and sugar to give jelly or is canned as a juice for beverage use.

Waste Sirup from Canning. It is estimated that the waste sirup from sealing and siruping machines in an eight-line fruit cannery involves a loss of 400 to 700 lb. of sugar per day. In the past this sirup has not been recovered in most canneries. A system and a machine have been developed for the recovery and refining of such waste sirup. It is gathered in drains beneath the siruping and sealing machines and is pumped to the refining equipment, where it is mixed and heated with decolorizing carbon and infusorial earth and is filtered in a small filter press. The sirup is freed of oil, color, and objectionable flavor by the refining process and can be used in canning of fruit of standard grade (Figure 106).

Olive By-products. In California most of the small olives—fruit damaged in pickling, frosted, and other cull olives—are utilized for oil.

Some of the small olives were formerly pickled and pulped in a tomato pulper equipped with a heavy specially constructed screen. The resulting "purée" was mixed with salt and spices and was then canned and sterilized. It was known as "olive mince," or "olive relish," and was used for sandwich fillings, sauces, and as a flavoring in cooking. Chopped pimientos, green peppers, and horse-radish give an excellent blend with olives. This product

has been replaced largely by canned unflavored minced olives prepared from small pickled olives pitted by machinery, chopped, and canned as a mince, or relish. The canned product requires a process of 240°F. for 90 min. (Chapter 9).

The pomace from olive-oil manufacture was utilized in California for fuel at one time. In Europe it is extracted with volatile solvents for recovery of the residual oil. However, a solvent plant is now recovering oil from olive pomace and refining it for food use in California.

Walnut By-products. The California Walnut Growers' Association has a membership of about 9,500 growers and handles about 85 per cent of the merchantable nuts of the state's crop in shell and about 75 per cent of the state's output of shelled walnuts. In the cracking of walnuts for recovery of the meats the shells are broken into many fragments and some of the meats are broken or scuffed into rather small pieces. Thus three products result: meats in rather large pieces or in halves that are packed for bakers' and confectioners' use and for use in the home, shells in large pieces that are separated mechanically from the meats and sold for by-product uses, and a mixture of small pieces of shell and small meat fragments that cannot be separated mechanically or economically separated by hand sorting.

J. A. Armstrong of the Association a number of years ago conducted experiments on separation of the shell and meat fragments by flotation and found on application for a patent on the process developed by him that a prior patent existed to F. B. Romberg of Holland, Texas, on a similar process for separating shell and nut-meat fragments encountered in the shelling of pecan nuts. Armstrong secured sole rights for use of the Romberg process as applied to walnuts and almonds. Also, he added certain improvements and refinements of his own and adapted the process and equipment for use with walnuts in the Association's plant.

The apparent specific gravity of the shells and the meats is essentially the same, and it is not feasible to separate them by flotation in their natural state. However, if the mixture of shell and nut fragments is held in water under high vacuum for about 1 hr. and the material allowed to soak for another hour, the air spaces in the shell fragments are filled with water and the specific gravity of these pieces is increased to about 1.25, while that of the good meat fragments remains at about 1.00 and that of the off-grade meats intermediate between that of the shells and the sound meats. In a brine of 20 to 30° salometer the fragments of sound kernels float and are skimmed continuously off the brine mechanically and the shell fragments and off-grade fragments of nut meats sink. They are removed automatically and continuously.

Next the salt is rinsed from the nut-meat fragments. They are then dewatered in a centrifugal extractor and dehydrated at about 145°F. in a tipping-tray dehydrater. The meats are then size-graded by suitable

machine into eight sizes, and each size blown separately to remove loose skins, chaff, and other light material. They are then carefully inspected on a slowly moving belt, and off-quality pieces removed by hand. The pieces are then packed in cartons lined with waxed paper for sale to bakers and confectioners.

The plant was put into operation in 1946 on accumulated shell and meat fragments from the previous season. From the 1945, 1946, and 1947 crops, 5,500 tons of sifting fragments were processed, from which 1,112,879 lb. of edible kernels was recovered. A return of $236,278 was realized over and above all operating expenses, according to a report of the California Walnut Growers' Association. The process is still in full operation.

A considerable tonnage of cull walnuts (sunburned, poorly filled, wormy, etc.) accumulates each season. They are unfit for use as human food in their natural state. They are used in a by-products factory in which they are ground and pressed in a powerful press for recovery of walnut oil. As this is a semidrying oil, it is in demand for use in paints with linseed oil, or to replace that oil. It is said to possess properties that make it especially useful in paints used by artists.

The shells from the cracking of walnuts are used by the by-products plant for producing a powder which finds many uses in various industries, such as a filling for linoleum and various plastics, filler for insecticidal dusts, wall-board filler, etc. The shells are also used as a fuel.

UTILIZATION OF VEGETABLE WASTE

In the canning of vegetables and the manufacture of tomato products a considerable proportion of the vegetables is discarded as waste or is often only partially utilized. Studies by Rabak and others have proved that waste tomato seeds and skins, in particular, are worthy of study for the preparation of by-products.

By-products from Tomato Seeds and Skins. Rabak (1917) estimated the average quantity of waste peels and seeds from United States tomato-product factories at 16,000 tons on a wet basis, or approximately 3,000 tons of dry material, of which about 1,500 tons are seeds and 1,500 tons dry skins. At present the quantity is considerably greater.

Drying Waste and Separating Seeds. The seeds must be separated from the skins before the oil is extracted. In Italy, according to Rabak (1917), the waste is passed through a continuous press to remove as much of the excess water as possible, and it is then dried in a continuous drier by a blast of air heated by steam coils. In a large California plant the waste skins and seeds are pressed in a continuous press, dried in a rotary-drum drier, ground in a hammer mill, and sold for use as stock food.

The seeds may be separated from the dried material by screening and fanning.

Extraction of the Oil. The oil is usually recovered in Europe by pressure in an expeller, i.e., continuous oil press, or by solvent extraction. A maximum of about 20 per cent of oil is obtainable by this means. The press cake may be combined with the dry peels for stock food.

Refining the Oil. The objectionable odor of the raw oil may be removed by treatment with a current of steam *in vacuo*, the excess acid may be neutralized with sodium carbonate or dilute sodium hydroxide, and heating with fuller's earth and filtration will remove excess color. The refined oil is suitable for food.

Centralized Plants Necessary. It is not feasible for individual canneries and tomato-products factories to undertake the manufacture of tomato by-products other than stock food. It would be possible, however, to dry the waste at the various plants and ship it to a centrally located plant to be converted into oil and stock food.

Asparagus Waste. In the cutting of asparagus stalks for canning, approximately 50 per cent is wasted. Some of the material is cut in short segments and canned for soup stock, but most of the waste is discarded. It contains 93 to 97 per cent moisture and can be dried for stock food. It has been found that a palatable concentrated soup stock can be obtained by evaporating *in vacuo* the juice expressed from the boiled stalks. The U.S.D.A. Western Regional Research Laboratory, Albany, California, has found that asparagus juice is an excellent medium for growing microorganisms for production of antibiotics, such as gramicidin, for use in combating infections. The butts are steamed and pressed, and the juice can be concentrated *in vacuo* for convenience of antibiotics manufacturers.

Waste from Pea and Corn Canning. The vines and pods from pea canning and the husks from corn canneries are seldom allowed to go to waste but are used as stock food, either in the fresh state, dried and cured as hay or fodder, or as ensilage. Pea vines are improved for siloing purposes if mixed with corn silage, for the reason that they are apt to undergo undesirable putrefactive changes in the silo unless mixed with other materials low in protein and rich in carbohydrates.

Green corncobs from canneries are rich in carbohydrates and may be used in the silo if finely shredded.

In the Pacific Northwest a large proportion of the waste pea vines is spread in the field and allowed to dry in the sun. The dry vines are then baled in the same manner as other hay and fed to livestock. Several canneries in that region place the green vines in pit silos in which they are compacted by track-type tractors. The ensilage is fed later to cattle. The cobs and husks from corn canneries and freezers are usually shredded into

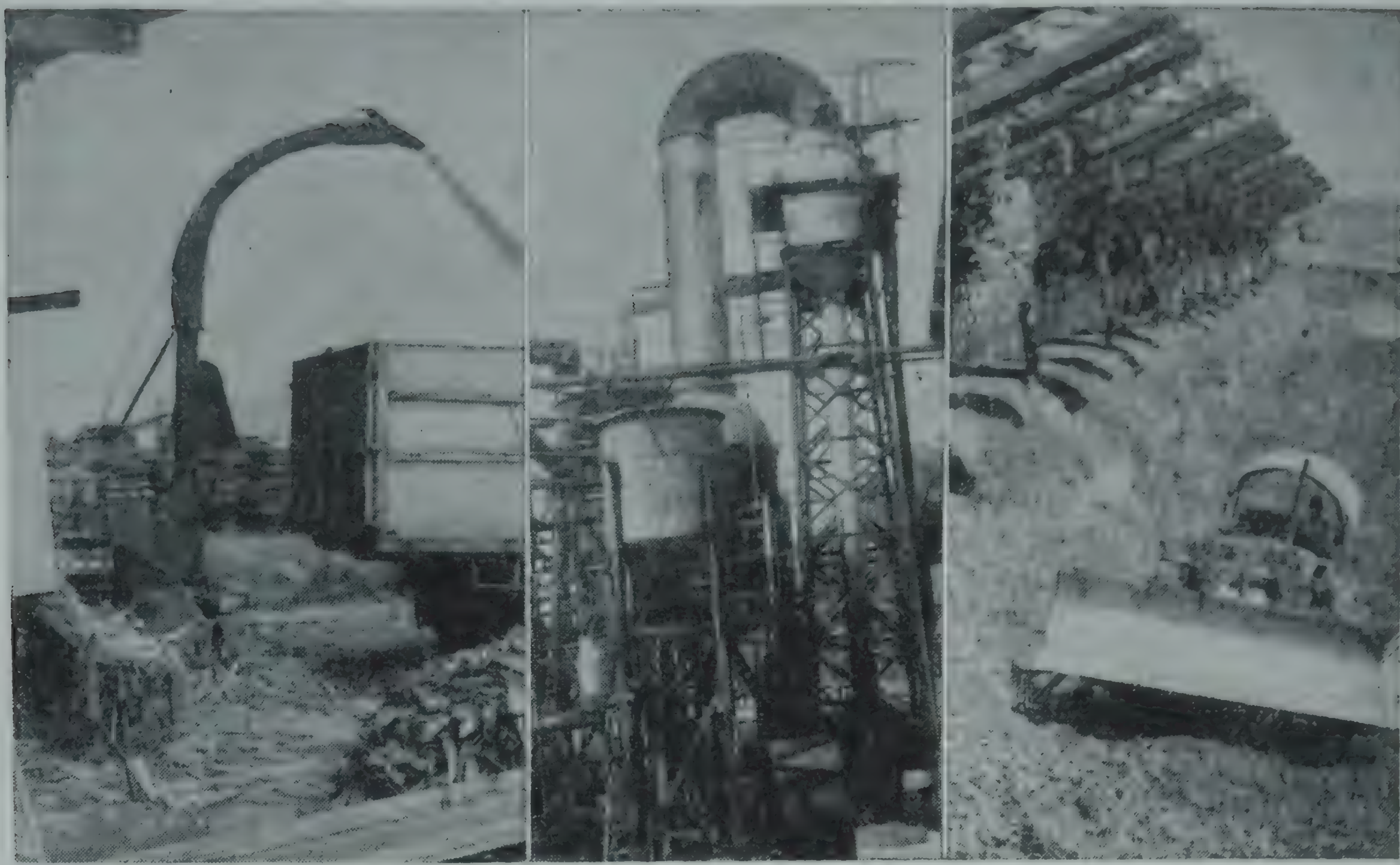


FIG. 105. *Left:* Shredding corn husks and cobs and loading into truck. *Center:* Vacuum pan for concentrating pear waste juice to molasses for stock feed. *Right:* Pit silo with waste Lima bean vines. Track-layer tractor compacting the vines.

waiting trucks for transportation to dairies and other livestock establishments, for feeding fresh or for ensiling.

Spinach crowns and trimmings are succulent but low in food value. They can be utilized profitably for feeding purposes if not allowed to become moldy or otherwise decomposed.

Vegetable Oils. The manufacture of by-products from cottonseed, soybeans, peanuts, sesame seed, corn germs, etc., although extremely important, does not logically fall within the scope of this book, because they are field-crop by-products rather than fruit or vegetable by-products. The subject of fixed vegetable oils is so important and the published literature is so extensive that a separate book would be required to do it justice (see references at end of this chapter).

DISPOSAL OF CANNERY AND OTHER WASTES

In addition to utilizing various fruit and vegetable wastes there is the problem of disposal of wastes from canneries, wineries, olive-oil factories, etc., in such manner that they do not unduly pollute streams or become a public nuisance. A great deal of attention has been given to this problem in Wisconsin, Ohio, and New York by the respective state boards of health and by the research staffs of the National Canners Association.

As stated by Mercer (1955), the state of California has defined in its antipollution legislation three classes of pollution, viz:

1. "Contamination" is the addition to a stream of materials which constitute a health hazard. This would include substances that harbor living disease-producing bacteria or materials toxic to human life.

2. "Pollution" is the result of adding to a stream materials in a concentration which adversely affects beneficial uses of the water. Discharge into a stream of materials causing destruction of fish life or interfering with use of the water for irrigation purposes would be termed pollution.

3. "Nuisance" has the meaning of causing damage to the stream or property or inconvenience to the public through unreasonable disposal practices. In this category would be included an odor nuisance produced by decomposing cannery wastes, or the discharge into a stream of highly colored waste waters.

Some states have standards of quality for stream waters and strength of effluents entering streams, but California has not set up such standards and tolerances for the state as a whole. Instead, a state Water Pollution Control Board has been established, which has adopted the policy of evaluating each control problem independently as it arises.

Mercer (1955) recommends that a cannery or other processing plant that is faced with a waste-disposal situation take the following steps. A survey should be made to determine the volume of liquid waste and the amount of solid wastes to be disposed of, whether or not they are potentially hazardous to public health; the amounts of soluble and suspended solids in the wastes; and the possibility of segregating highly contaminated waste waters from waters that have little or no contamination, such as the cooling water from the can-processing lines, condenser water, etc., as such waste water will not require treatment. A study should be made of possible re-use of much of the water, such as that used in cooling cans of heat-processed products, condenser water, etc. However, it must be realized that improper re-use of water may lead to bacteriological problems (see Mercer and Townsend, *National Canners Association Bulletin* 31–L). Means of removing as much of the suspended solids from the wastes should be carefully studied, and adequate screening equipment installed. The plant should investigate the several methods of liquid-waste disposal now in use, such as discharge into the local sewage-disposal system after screening to remove suspended solids or other treatment to render the waste acceptable in the city's sewage system; lagoon disposal of the liquid wastes; biological treatment; and disposal of liquid wastes by irrigation. Plans for future expansion of the cannery's plant will also probably be involved.

Regardless of the ultimate method adopted for waste disposal, it is essential to remove by screening as much of the suspended solid wastes as possible. Such solid wastes may overload lagoons or digesters, foul up municipal sewage-disposal facilities, cause unsightly accumulations in streams, reduce the oxygen supply in streams to the point where fish are

killed, clog filters and sprinklers, and in other ways increase the problem of waste disposal. Most state boards of health or other state agencies require the screening of such wastes.

Screens used for this purpose are of three general types: (1) rotating drum screens, in which the solids are retained on the inside of the screen and the waste water passes through and out, the solids being washed from the screen by sprays; (2) vibrating table-type screens which have the advantage that finer screens can be used than on the drum type; and (3) gyrating circular screens.

The solid wastes screened out in any one of these devices are elevated to a large outdoor hopper from which they may be drawn by gravity into dump trucks for transportation to a livestock feed yard or to the dump. In some cases livestock operators will take such wastes at no cost to the canner; in others the canner or freezer or other plant will have to pay for this service.

The average cannery liquid wastes have about ten times the load of putrescible organic matter as does domestic sewage; in some cases it may be much greater than this and in others less. This load is often termed the B.O.D. (biological oxygen demand). According to the research department of the National Canners Association (1953), the B.O.D. of domestic sewage is usually considered to be about 200 p.p.m. on a 5-day B.O.D. basis compared with B.O.D. values found for a pea-cannery waste of 1,097 p.p.m., 2,039 p.p.m. for a cannery packing mixed carrots and peas, and 5,953 p.p.m. for one canning beets. In all three cases it was found possible to reduce the B.O.D. to less than 200 p.p.m. by use of aerated digestion treatment, as described later in this section. The treated wastes in these cases would then probably have been acceptable for disposal via a municipal sewage-disposal system. Canneries located in large cities, such as San Francisco and Oakland, California, are able to dispose of the untreated wastes directly in the cities' sewage-disposal systems. Where such disposal is used, the city often makes a suitable charge for the service.

In many localities, as in the corn- and pea-canning areas of the Middle West and Pacific Northwest, the cannery or freezer must assume the entire load of waste disposal. One common method is by screening to remove suspended solids, followed by disposal of the liquid waste in a large shallow lagoon. If the waste is untreated, anaerobic bacterial action eventually destroys most of the organic matter but also results in the development of objectionable odors that may be obnoxious for a distance of a half mile or more "downwind." Such operation of lagoons makes their location at a considerable distance from human habitations necessary. Results of research by the National Canners Association show that by addition of commercial-fertilizer-grade sodium nitrate to the liquid waste, biological oxidation of the organic matter by microorganisms is promoted, with prevention of obnoxious odors. The nitrate is added to the waste on its

way to the lagoon or digester and must be added daily to the waste stream. The amounts of nitrate required per 1,000 cases of various products are given by the National Canners Association as follows: for green beans 20 lb., beets 200 lb., corn 200 lb., peas, early, 200 lb. and peas, late, 150 lb. At a cost of 4 cents per pound for the nitrate the cost per case for early peas and corn on the basis given above would be 0.6 to 0.8 cents.

Lagoons should be so located that seepage to underground water levels does not contaminate the domestic water supply of nearby residents. Mercer (1955) states that the depth of the lagoon should be not more than 3 ft. and that 5 ft. is the maximum, as septic conditions, indicated by obnoxious odors, etc., quickly develop in deep lagoons. Growth of weeds should not be permitted as they add to the disposal load.

As outlined by Mercer, aerobic digestion of the screened waste can be accomplished in a tank by continuous diffusion of air into the liquid. A good population of the proper types of bacteria and a pH range suitable to their growth are essential. Most of the organic matter in the waste is destroyed. A second treatment usually follows, viz., sedimentation in a second tank or lagoon. Addition of nitrate as mentioned above is usually more practicable than aeration, as a source of oxygen.

Chemical treatment of the screened waste with lime and ferrous sulfate or alum has been used to reduce the B.O.D. According to Mercer, lime is added first in a tank used for that purpose and the ferrous sulfate or alum is added to the lime-treated waste in a second tank. After settling, the clarified liquid is drawn off and the sludge removed to a drying bed. Such treatment, however, removes only part of the organic material responsible for the B.O.D. Additional treatment is needed.

In recent years the disposal of the screened liquid wastes from canneries and freezers by spray irrigation has come into use in many localities, as in the Middle West and the Pacific Northwest. A considerable area of suitable land is required, preferably level or nearly so and sufficiently porous to permit fairly rapid percolation of the water into the soil. A good cover crop such as of grass or alfalfa or clover, or other, is essential for best results. The site must be within practicable pumping distance of the plant. A small lagoon or tank receives the screened liquid waste and serves the purpose of providing a steady supply to the irrigation pump; usually it will hold a supply of 4 to 5 hr. If too large septic conditions may develop with obnoxious odors. The liquid is pumped through movable aluminum pipe of suitable diameter to large spray nozzles. If the soil is absorptive and porous, several inches of water may be sprayed on a plot of the land in a day. The nozzles and pipe would then be moved to a second plot for the following day's operation, and so on throughout the season. Each plot will receive several irrigations during the campaign. If the land is a heavy adobe or a shallow soil underlain with clay, less liquid can be sprayed on a given plot

per day and a greater total area will be needed. Results on bare soil have not been very satisfactory because of erosion and coating of the surface with "muck and slime." A good cover of grass, clover, or alfalfa is desirable as it prevents erosion, provides feed for livestock, and uses much of the water applied to the soil. A wooded area is usually satisfactory.

If the waste liquid is not properly screened, the spray nozzles will become plugged. Seepage from stacks of pea vines that have become septic (foul-

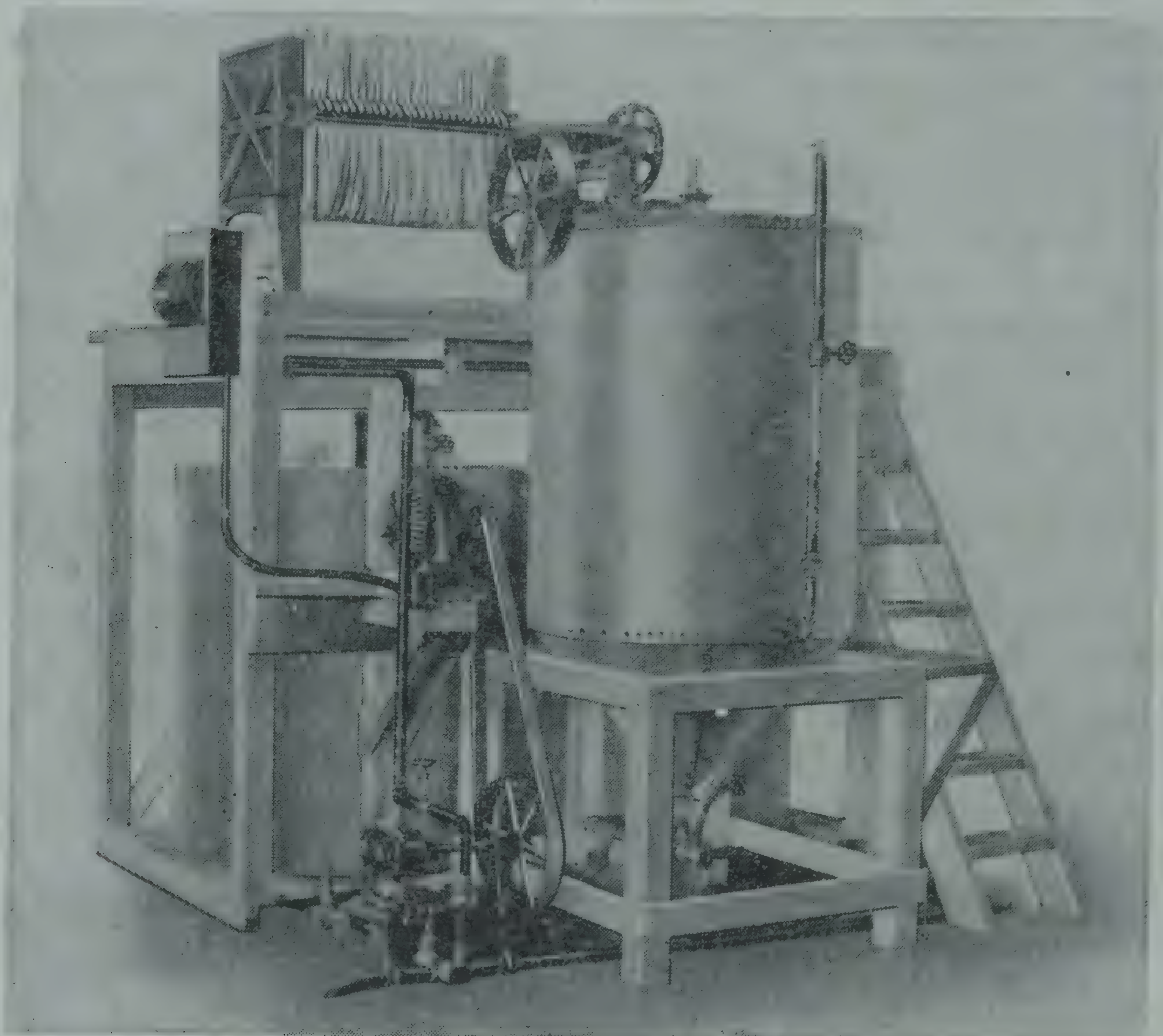


FIG. 106. Refining equipment for waste sirup in canneries. Hiller's design. (*Berger and Carter Co.*)

smelling) should not be allowed to enter the waste water because severe damage to vegetation will ensue.

Sanborn (1952) has given an excellent report on spray irrigation as a means of disposing of liquid wastes from canneries (see also the National Canners Association, Research Department, Annual Reports, especially 1950 to 1955).

In Ohio experiments trickle filtration through stone or lath filters under aerobic conditions at the rate of 2 million gal. per acre per day, i.e., 250,000 gal. per acre-foot, gave good results with the screened but not chemically treated liquid wastes. Clogging and sludge formation did not occur. Sand filters also gave satisfactory effluents, although at a lower rate per acre per

day. While it is usually effective after it attains full efficiency, it is costly and difficult because used for such a short period each year.

In California the disposal of waste still liquids from wine-brandy stills is a serious problem. From experiments conducted by H. E. Jacob of the University of California, and later by Vaughn, Marsh, and Fisher, it appears feasible to run the waste liquid into a plot of idle land for a few days, let it soak into the ground, plow or cultivate the plot, and let it lie idle for a few days while other similar plots are receiving the waste. Then the first plot may be used again, and the cycle repeated until the soil becomes clogged. For a considerable period the soil sometimes remains toxic to plants. Evidently biological oxidation occurs in the cultivated soil and thus removes much of the organic matter.

Tartrates may be recovered by treatment with lime, as previously described. The resulting effluent is then more readily treated by trickle filtration, especially if diluted with several volumes of water. Still-waste liquids ("still slops") are highly putrescible. In sufficient concentration, they kill fish in streams, and if applied in too great quantity to vineyard soils, kill vines.

Feeding Value of Fruit and Vegetable By-products. A great many feeding tests have been conducted by the Animal Husbandry Department of the University of California on the use of various fruit and vegetable wastes and by-products in order to assay their value as foods for livestock.

In one experiment by Miller lambs were fed as follows:

Lot 1......... Whole barley and alfalfa hay. Check lot.
Lot 2......... Whole barley 1 part, cull raisins 2 parts, alfalfa hay.
Lot 3......... Whole barley 1 part, raisin pulp 2 parts, alfalfa hay.
Lot 4......... Whole barley 1 part, stemmer waste 2 parts, alfalfa hay.

In this experiment the cull raisins were those rejected at the packing plant as unfit for human consumption; raisin pulp was a by-product from the manufacture of raisin sirup, i.e., the dried extracted raisins plus raisin-seeder waste and raisin-stemmer waste. The chemical composition of the materials fed in this experiment is given in Table 49.

TABLE 49. CHEMICAL COMPOSITION OF FEEDS USED IN RAISIN-BY-PRODUCT FEEDING TEST

Feed	Moisture, %	Ash, %	Crude protein, %	Crude fiber, %	Nitrogen-free extract, %
Barley	9.79	2.25	11.30	7.07	67.25
Cull raisins	18.50	3.34	2.72	3.09	71.74
Raisin pulp	12.14	4.66	9.46	13.06	53.28
Stemmer waste	13.20	10.14	7.50	15.44	49.32
Alfalfa hay	8.85	9.26	15.03	32.45	32.30

SOURCE: After Miller.

The feeding trials lasted 84 days. The lambs of lot 1 gained 24.14 lb. each; lot 2 gained 24.03 lb. per lamb; lot 3 gained 23.20 lb. per lamb; lot 4 gained 22.10 lb. per animal. Gains were lowest on the stemmer waste. It included some ground waste raisin seeds.

Other by-products that were used in feeding tests with cattle, sheep, or hogs were dried pineapple pulp, winery pomace, dried lemon-peel pulp, dried olive pomace, orange pulp (chiefly dried peel plus molasses from peel juice), cull prunes, dried cull avocadoes, dried waste asparagus butts, cull dried figs, almond hulls, dried apple pomace, cull dried peaches, and cull dried apricots. Data were taken similar to those given above for the raisin by-products.

Most of these products were fairly satisfactory when fed as part of the animal's ration. However, in some cases scouring (diarrhea) occurred if too much of certain dried fruits was fed. In most cases gains in weight were satisfactory and economical in cost. Dried orange and lemon peels from citrus-by-products plants are now standard feeds for dairy cows and feeder steers. Cull prunes, cull dried figs, and cull raisins are in good demand as stock feeds. None of these fruit by-products are fed alone, but are always fed with other common livestock feeds such as alfalfa hay, cottonseed meal, and others. When used as part of the ration they are valuable additions to the animal's menu. For chemical composition and the detailed results of feeding tests, see references at the end of the chapter.

Stock Feed from Cannery Waste. As reported by Richardson (1952) a process and equipment for converting pear peels and cores and other fruit wastes from canneries into a stock feed have been developed by the U.S.D.A. Western Regional Laboratory. A factory for commercial production was established near San Jose, California, by the Canners' League and the Canning Peach Association, both of California, and operated for several years.

In brief, the procedure was about as follows: The fruit waste was ground or puréed and treated with lime to a critical controlled pH value for the purpose of causing flocculation, in order that the juice could be separated from the pulp effectively and economically; the solid and liquid fractions were separated by filtration on a special drum-type filter; the juice was concentrated to a heavy molasses in a triple-effect vacuum concentrator; the solid fraction was dried in a rotating-drum, flame-type dehydrater; and the two products combined to give the final mixture, a stock feed. Feeding experiments at the University of California with sheep and cattle proved the material to be a good feed, comparable in value to beet pulp mixed with beet molasses. Pear peels and cores were the principal raw material employed; nevertheless the process and equipment are adaptable to other fruit wastes such as apple peels and cores, cull peaches, plums, etc.

Pear Sirup. Chong and Cruess (1949) found that a sirup suitable for use in canning pears or for table use can be made from waste pear peels and

cores by first steaming them to destroy oxidase and other naturally occurring enzymes, cooling to 130°F. or lower; pulping; adding a pectic enzyme such as Pectinol (Pectinol 0, 2 grams per 1,000 grams of pear pulp), allowing the enzyme to act several hours; pressing in an apple juice press; filtering the juice; decolorizing with vegetable carbon, if a colorless sirup is desired; and concentrating *in vacuo*. Unless the pectic enzyme is used, it is impossible to press the pear waste. The waste must be free of spray residue if the sirup is to be used for human consumption.

REFERENCES

Binder, R.: Raisins in candy, *Mfg. Confectioner*, April, 1954.

Brown, E. M.: Slop and waste disposal [from wineries], *Wine Rev.*, **12**(7), 13–15, 1944.

Chong, G., and Cruess, W. V.: Obtaining juice from waste pear peels and cores, *Fruit Products J.*, **29**(3), 70, 72, 91, 94, November, 1949.

Cruess, W. V.: Utilization of fruits in food products, *Food Technol.*, **9**(9), 419–426, 1955.

———: Debittering of apricot kernels, *Fruit Products J.*, **21**(12), 365, August, 1942.

———: Utilization of surplus plums, *Univ. Calif. Agr. Expt. Sta. Bull.* 400, 1926.

———, Brekke, J., and Seagrave-Smith, H.: Experiments on almond products, *Univ. Calif., Dept. Food Technol. Rept.*, 1949. Mimeographed.

———, Friar, H. F., Jang, R., Lawrence, D., Miller, G., and Cytron, B.: Investigations on fruit products, *Fruit Products J.*, **28**(11, 12), 324–329, 363–365; **29**(1–4). 15–17, 46–48, 77–81, July–December, 1949.

———, Kilbuck, J. H., and Hahl, E.: Utilization of almond hulls, *Chemurgic Digest*, **6**(13), 197–201, July 15, 1947.

——— and Marsh, G. L.: Utilization of California fruits, *Univ. Calif. Agr. Expt. Sta. Circ.* 349, October, 1941.

———, Musco, D., and Binder, R.: Canning of raisin pie filling, *Canner*, vol. 117, May, 1953.

Drake, J. A., and Bieri, F. K.: Disposal of liquid wastes by the irrigation method of vegetable canning plants in Minnesota, *Proc. 6th Ind. Conf.*, Purdue University, 1951.

Felton, G. E.: Use of ion exchanges in by-product recovery from pineapple waste, *Food Technol.*, **3**(2), 40–42, 1949.

Folger, A. H.: The digestibility of ground prunes, winery pomace, avocado meal, asparagus butts and fenugreek meal, *Univ. Calif. Agr. Expt. Sta. Bull.* 635, 1940.

Friar, H. F., Cruess, W. V., and Seagrave-Smith, H.: Fruit granules and powders, *Fruit Products J.*, **26**(8), 228–230, April, 1947.

Hendrickson, R.: Florida citrus molasses, *Florida Agr. Expt. Sta. Bull.* 469, April, 1950.

Hughes, E. H.: The feeding value of raisins and dairy by-products for swine, *Univ. Calif. Agr. Expt. Sta. Bull.* 440, 1927; *Bull.* 342, 1922.

Jamieson, G. S., Bangmann, W. F., and Hann, R. M.: Avocado oil, *Oil & Fat Inds.*, July, 1928, pp. 202–206. Also book by same author on oils and fats, Chemical Catalog Company, Inc., New York, 1932.

Kimberley, A. E.: Cannery waste treatment studies, Ohio State Board of Health, 1927.

Marsh, G. L.: Recovery of tartrates from winery wastes, *Wine Rev.*, August, 1944. See also special report of Wine Institute by Marsh, Vaughn, and Fisher on disposal of distillery waste.

——— and Cruess, W. V.: Experiments with asparagus butts, *Fruit Products J.*, **21**(11), 333–336, July, 1942.

Marx, C., and Cruess, W. V.: Oil from grape seeds, *Proc. Inst. Food Technol.*, 1943, pp. 196–201.

Mead, S. W., and Guilbert, H. R: The digestibility of dried orange pulp and raisin pulp, *Univ. Calif. Agr. Expt. Sta. Bull.* 409, October, 1926.

Mercer, W. A.: Cannery waste disposal and its problems, *Canning Trade*, Apr. 25 and May 2, 1955.

——— and Townsend, C. T.: Water reuse in canneries, *Natl. Canners Assoc., Research Lab., Bull.* 31-L, May, 1954.

Miller, R. F.: Raisin by-products and bean screenings as feeds for fattening lambs, *Univ. Calif. Agr. Expt. Sta. Bull.* 431, 1927.

Monson, H. G.: Vegetable cannery waste disposal, *Canner*, **116**(24), 14–17, June 15, 1953.

Moore, C.: Methods of grape pomace disposal, *Wine Rev.*, **5**, 18, 19, December, 1937,

Mrak, E. M., and Cruess, W. V.: Utilization of surplus prunes, *Univ. Calif. Agr. Expt. Sta. Bull.* 483, 1929.

Musco, D., and Cruess, W. V.: Fruited breakfast cereals, *Am. Miller*, December, 1953.

———, and Yanase, K., and Lee, L. J.: Sirups made from low grade raisins, *Food Packer*, November, 1954.

National Canners Association Research Laboratories: Annual Reports, 1950–1956, Washington, D.C. See sections in each report on cannery waste disposal.

Pickett, J. T.: Huge feed source discovered, *Calif. Farmer*, Oct. 20, 1951, pp. 380–382. Use of almond hulls.

Rabak, F.: The utilization of waste tomato seeds and skins, *U.S. Dept. Agr. Bull.* 632, 1917.

———: Peach, apricot and prune kernel by-products, *U.S. Dept. Agr., Bur. Plant Ind., Bull.* 133, 1908.

——— and Shrader, J. H.: Commercial utilization of grape pomace and stems, *U.S. Dept. Agr. Bull.* 952, 1921.

Regan, W. M., and Gordon, G. E.: Fruits and fruit by-products as dairy cattle feeds, *Univ. Calif. Agr. Ext. Serv., Circ.* (not numbered or dated).

Report of the Chief of the Bureau of Agricultural and Industrial Chemistry, U.S. Department of Agriculture, 1945–1955. See sections on utilization of cull and surplus fruits and vegetables.

Richardson, A. C.: Utilization of waste from canning of deciduous fruit, *Proc. 45th Ann. Conv., Natl. Canners Assoc.*, Washington, D.C., Jan. 30, 1952.

Sanborn, N. H.: Spray irrigation as a method of cannery waste disposal, *Proc. 45th Ann. Conv., Natl. Canners Assoc., Inform. Letter* 1371, Jan. 30, 1952.

Scott, H. R.: More profits from pits, *Sunsweet Standard*, **6**(7), 17, 25, 26, December, 1922.

Strachan, C. C., Atkinson, F. E., Moyls, A. W., Kitson, J. A., and Britton, D.: Canned pie fillings, *Can. Food Inds.*, November, 1954.

Stream pollution in Wisconsin, *Wisconsin State Bd. Health, Bur. Sanitary Eng., Spec. Rept.*, 1927.

U.S. Department of Agriculture, Western Regional Research Laboratory: Process for production of asparagus juice concentrate, *Canner*, **100**(12), Mar. 31, 1945.

Vaughn, R. H., and Marsh, G. L.: The disposal of dessert winery waste, *Wine Rev.*, **13**(11), 8–11, November, 1945.

Vibrating separator screens waste water, *Canner*, **117**(2), 16, July 13, 1953.

Warwick, L. F., McKee, F. J., Wirth, H. E., and Sanborn, N. H.: Methods of treating cannery waste, *Natl. Canners Assoc., Research Lab., Bull.* 28-L, December, 1939. See also *Bull.* 29-L by same authors on the disposal of cannery wastes in lagoons.

CHAPTER 24

CITRUS BY-PRODUCTS[1]

In all the principal citrus-fruit-growing regions of the world the utilization of fruit unsuitable for fresh shipment has become a serious problem. For many years Sicily and other citrus-fruit-growing sections of Italy have produced essential oils, citrate of lime, citric acid, and other citrus by-products for export. In California an important citrus by-products industry has been developed over the past forty years. Among the more important products are essential oils of lemon and orange, pectin, citric acid, orange and lemon concentrates, canned orange juice, and dried peels for sale as stock feed. In Florida a very large canning industry has developed for grapefruit and orange juices and frozen citrus concentrate. Essential oil of orange, stock feed from waste peels, and other products are also made. For many years canned grapefruit sections has been a standard article in the canned-foods trade. Most of it is packed in Texas and Florida. Texas also packs a large amount of canned grapefruit juice. In Egypt, India, and Palestine progress is being made in establishing a citrus-by-product industry. Some orange juice and concentrate have been made in Australia.

MANUFACTURE OF CITRIC ACID IN CALIFORNIA

Citric acid is used in large quantities in various ways, as in the acidification of carbonated beverages (soda waters), in pharmaceutical preparations such as citrate of magnesia, and in candies, fountain sirups, jams, jellies, preserves, and in the dyeing of fabrics. At one time all citric acid of commerce was made from lemons. A few years ago its production from waste juices from pineapple canning was established, and at present a considerable quantity is produced by one of the large pineapple canneries in Hawaii. The most formidable competitor of citric acid from lemons, however, is that made by the action of *Aspergillus* mold grown on diluted molasses.

[1] The author is greatly indebted to H. H. Holton, G. M. Cole, and associates of the Exchange Lemon Products Company of Corona, California, and to C. R. Havighorst of the McGraw-Hill Publishing Company, Inc., for much of the information presented in this chapter.

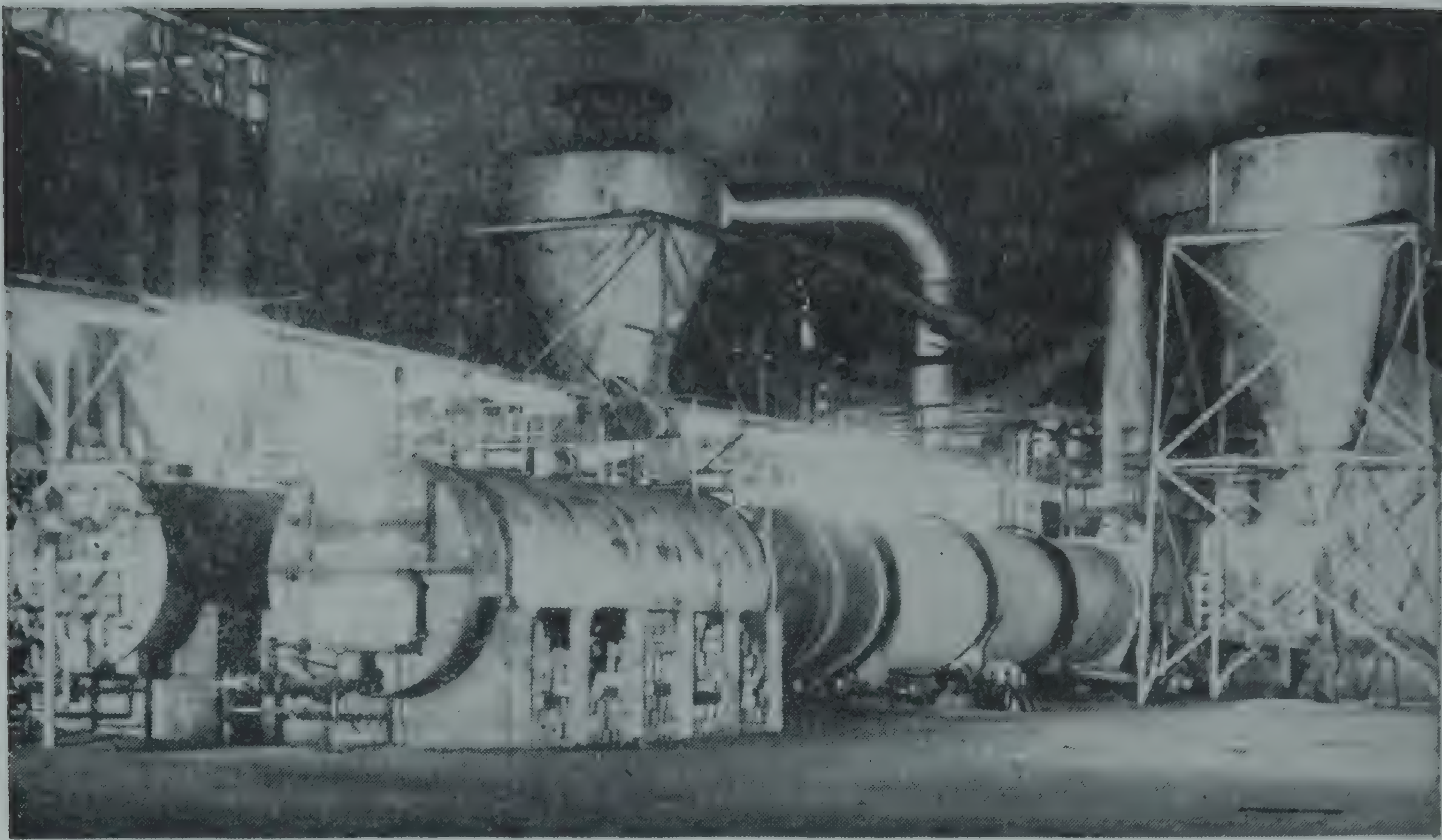


Fig. 107. Direct-fired drum dehydraters for drying waste orange peels at Exchange (Sunkist) Orange Products Co. plant, Ontario, Calif. (*Food Industries.*)

Raw Material. Cull lemons from the fresh-fruit packing houses are the usual raw material. Most of the lemons are sound and practically free from decay.

The fruit is shipped to the factory loose in boxcars holding about 20 tons or in trucks and trailers holding a like amount.

In California the manufacture of citric acid and essential oil of lemon was pioneered by the California Fruit Growers' Exchange with the assistance and cooperation of the Fruit and Vegetable Products Laboratory of the U.S.D.A., of which E. M. Chace was director at that time.

Extraction of the Juice. The fruit first passes through a tank of water that removes leaves, twigs, and other refuse. It is then elevated to bins and ground coarsely, so that much of the juice is freed. The pulp is then sprayed and pressed in a continuous press in order to recover as much of the juice as possible. The resulting combined juice varies from 3.5 to 5 per cent in citric acid content.

The juice is next run through a revolving perforated reel which removes the coarsest pulp; and it is then centrifuged to recover the essential oil.

Fermentation of the Juice. The freshly expressed juice is not satisfactory for processing because of the presence of fine suspended pulp which would contaminate the citrate and which, because of its gelatinous nature, would make filtration extremely slow and difficult. The fresh juice, therefore, is stored in tanks holding up to about 40,000 gal. and in which spontaneous alcoholic fermentation ensues. During fermentation the naturally occurring pectic enzymes of the juice destroy the pectin in the juice, and thus its

sliminess. The heavier particles of peel settle to the bottom, and the fines rise to the surface to form a cap. The fermentation requires about 5 days in warm weather and about 10 days in cold weather. The juice below the cap and above the sediment is relatively clear. Very little citric acid is lost during fermentation. If, however, the juice is allowed to stand too long, film yeasts develop and rapidly destroy the citric acid. Excessive dilution of the juice results in a similar loss. The juice must be handled promptly after fermentation is complete.

Boiling and Filtration. Ordinarily only the pulpy cap and sediment layers need be filtered. Therefore the clearer juice is drawn off for processing without filtration and infusorial-earth filter aid is added to the sludge in the tank. It is then steamed until a settling test indicates that filtration will be satisfactory. The hot juice is then filtered in wooden-frame filter presses or others of suitable corrosion-resistant material. The filtrate is brilliantly clear and light amber in color. It is mixed with the previously separated unfiltered juice for citrate precipitation.

Precipitation of the Calcium Citrate. Neutralization of the juice with calcium hydroxide results in the formation of insoluble calcium citrate. This is brought about as follows: The mixed juice, plus some mother liquor to reinforce the acidity, is placed in a wooden tank equipped with a mechanical agitator and steam coils or open steam line. The juice is boiled a short time to coagulate the fine suspended solids, and then a slurry of hydrated line is added slowly until the local darkening of the juice indicates that the end point is near. Further additions are made as needed to leave only a slight acidity in the juice as shown by titration. If the juice is completely neutralized it becomes dark, and also some metallic contaminants precipitate, all of which results in inferior calcium citrate. The entire neutralization procedure is conducted with the hot juice, as calcium citrate is insoluble in the hot liquid and somewhat soluble in the cold.

When the reaction is complete, the hot slurry of citrate and liquid is pumped to the filters.

Filtration. As the citrate is less soluble in the hot juice than in the cold, the filtration must be conducted while the liquid is still hot. Plate-and-frame filter presses are used for the filtration. The solid citrate accumulates between the leaves of the press and eventually fills them. The citrate is then washed in the filter press with hot water, and then air is blown through the press to remove much of the moisture. Citrate cake not needed for immediate production is dried and stored.

Decomposition of the Citrate. The filter cake is then mixed with the wash water from a previous lot of calcium sulfate to form a thin paste. A calculated amount of sulfuric acid of 66° Baumé is added and mixed with the paste and agitated until the reaction is complete. Not more than 0.2 per cent of free sulfuric acid should be present after the reaction is complete.

The end point is determined by testing the liquor with methyl violet indicator paper, the end point being indicated by a change in color from violet to blue.

A slight excess of sulfuric acid aids in the crystallization of the citric acid, but a large excess will cause darkening of the acid liquors by caramelization and will cause the finished citric acid crystals to be dark in color.

Filtration to Remove Gypsum. In the decomposing tanks calcium sulfate (gypsum) is formed as an insoluble precipitate and the citric acid goes into solution. The acid liquor has a density of 8 to 10° Baumé and an acid content of 15 to 18 per cent citric acid.

The calcium sulfate precipitate is removed by means of a plate-and-frame filter press after addition of filter aid. It may be dried and used by orchardists or other farmers to ameliorate the texture of heavy soils of slightly alkaline character, of which there is a large acreage in California. The filtered liquid is brilliantly clear and of light amber color.

Concentration of the Acid Liquor. According to Chace (1940), the clear liquor may next be partially evaporated in shallow lead pans in which it is heated by steam coils. During the heating the liquor is agitated by compressed air or other means. However, according to a flow sheet by Holton and Havighorst (1953), this preliminary concentration is now conducted in a vacuum pan. The partially concentrated liquor is allowed to settle in a tank and is then drawn off from the calcium sulfate sediment, because as concentration proceeds, the decrease in volume causes the small amount of calcium sulfate remaining after sulfuric acid treatment to precipitate.

Concentration is then continued in a vacuum pan to 37 to 39° Baumé, which results in a supersaturated citric acid solution.

First Crop of Crystals. The concentrated solution from the vacuum pan is pumped into small lead-lined tanks equipped with agitators and situated in a refrigerated room. The liquor is slowly cooled for 4 or 5 days, during which a heavy crop of granular citric acid forms.

Centrifuging. The magma mass of crystals and mother liquor is placed in a centrifuge basket, the mother liquor is spun off, and the crystals are washed with sprays of cold water to remove adhering mother liquor. The mother liquor is of dark color but yields a second crop of crystals by concentrating and crystallizing. When the mother liquor no longer yields desirable crystals, it is sent to the neutralizing tanks, diluted with water, partially limed, and mixed with the fresh juice so that none of the acid will be discarded.

Dissolving the Crude Crystals and Removal of Metallic Salts. The centrifuged crystals are dissolved in water in a rubber-lined tank. The impurities to be removed are (1) organic coloring matter, (2) lead, copper, tin, and antimony salts, (3) iron and nickel salts, and (4) sulfuric acid.

The organic coloring matter is removed by warming the liquor with

about 0.5 per cent of its weight of high-quality decolorizing carbon. Sulfuric acid, if present, is removed by adding barium carbonate to the liquor.

Hydrogen sulfide water is added to precipitate the lead, tin, copper, and antimony salts, which may have been dissolved by the acid solutions during their passage through pipes, by heating in lead tanks, or by contact with metals at other points in the process.

The amount of calcium ferrocyanide found necessary by laboratory test to precipitate the iron and nickel salts is added to the acid liquor. If left in solution, the iron and nickel salts would discolor the final crystals and render them unsalable as U.S. Pharmacopoeia citric acid.

The char is added first and then the reagents, and after mixing, the liquor is filtered through cloth in a plate-and-frame filter press.

Concentration *in Vacuo*. The filtered acid solution is again concentrated in a vacuum pan with outside heater to 36 to 37° Baumé (at 50°C.). A glass-lined vacuum pan is used for this concentration.

Final Filtration. The concentrated liquor is again filtered to remove small amounts of insoluble salts that have separated from the solution.

Final Crystallization. The filtered concentrated liquor is run into jacketed stainless-steel granulators equipped with mechanical agitators. Cold water is circulated through the jacket to reduce the temperature of the mass slowly to room temperature or lower and thus to hasten the crystallization of the acid.

Centrifuging the Final Crystals. The crystals are spun in a basket centrifuge and washed therein with fine sprays of water. The washings are recovered and mixed with other acid liquors for dissolving crude acid and repeating the cycle.

Drying the Crystals. The crystals are dried in a rotary drier through which flows a current of warm, dry air. They are next screened into three sizes and packed in paper-lined kegs and barrels. The purity of the acid is closely controlled so that it will meet the requirements of the United States Pharmacopoeia.

CALCIUM CITRATE AND LEMON-OIL MANUFACTURE IN ITALY

Considerable citric acid is made in Italy, although a larger amount of the intermediate product, calcium citrate (usually known in the trade as "citrate of lime"), is produced and exported. Oil of lemon is also produced on a large scale for export. Other Italian lemon by-products are salted peel and concentrated lemon juice.

The preparation of oil and citrate is conducted under one roof and from the same fruit, hence the necessity of considering the two processes together.

According to Powell and Chace, Italy at one time exported approximately 17 million lb. of citrate of lime. They also state that the normal amount of lemon oil exported from Italy was approximately 1 million lb. annually. The Second World War disrupted the industry badly.

Extracting Oil. The oil is usually extracted by hand, two methods of preparing the rind being used. In the three-piece method the rind is removed in three strips lengthwise of the lemon. In the two-piece method the lemon is cut in half and the flesh is scooped from the fruit by means of a sharp spoon. The pulp from either method of peeling is used for the preparation of juice for citrate, and the rind is used for oil.

The peels are pressed by hand over a bowl; the juice and oil are caught by sponges and are periodically pressed into the bowl. The oil is decanted from the juice by tilting the bowl forward and blowing the breath on the surface of the oil.

The oil is allowed to settle for 24 hr. and is then filtered through paper and stored in large copper cans, which exclude light and thus minimize deterioration.

The residue from the bowl contains considerable oil, which is recovered by distillation in crude stills. Distilled oil is of poor quality and becomes "terpeney" (of turpentine-like odor) rapidly but is often used in adulterating the hand-pressed oil.

Chace states that in Calabria, lemon oil and oil from the rinds of oranges are obtained by use of a machine in which the whole fruit is placed between two disks which have rough abrasive surfaces and one of which revolves. The outer portion of the rind is grated from the fruit, the grated fruit is wiped with a sponge, and the juice and oil so collected are expressed from the sponge. The oil is of excellent flavor, is darker in color than the hand-pressed oil, and is used largely for blending with the latter to intensify its color. In 1924 the present author saw machines of the ecuelling type in use in Sicily. The whole fruit passed over hundreds of needles, which punctured the oil cells and liberated the oil. The oil was washed off the fruit by a fine spray of water and was recovered by centrifuging. In Messina and vicinity in Sicily are located several modern plants for the recovery and purification of lemon oil by mechanical means. Consequently, the sponge process is declining in importance.

Citrate of Lime. The pulp or peeled fruit from the oil room is crushed by wooden rollers operated either by mechanical means or by hand power. The crushed fruit is placed in heavy, closely woven straw bags, and these are placed one above the other and subjected to heavy pressure in a large screw hand press, the bags acting as filters as well as press cloths.

The juice is placed in a tank, in which it is heated nearly to boiling by a steam coil or by direct heat, and milk of lime is added until the liquid is neutral to litmus paper. After heating for several hours, the hot liquid is

placed in a tank fitted with a filtering cloth on which the citrate collects as a voluminous white powder. After the liquor has drained off, the citrate is shoveled into small bags and pressed to remove excess liquid.

It is removed from the bags to iron pans, which are stacked on racks in a room heated with a large charcoal burner, and there dried.

The dry citrate is broken into small pieces and packed in hogsheads holding about 675 lb. each. Each lot is sampled, analyzed, and sold to brokerage houses. The citrate usually contains more than 60 per cent of citric acid.

Citric Acid. The citrate before the Second World War was converted into citric acid in Germany, England, and the United States by methods similar to those described earlier in this chapter. At that time also Palermo, Sicily, had a very large modern factory in which citric acid was produced for both export and domestic purposes. This plant survived the Second World War and is still in operation (1957).

Yields. Chace states that 100,000 lemons (10 to 12 tons) yield 100 lb. of oil and 675 lb. of citrate of lime. This corresponds to 8½ to 10 lb. of oil and about 56 to 67 lb. of citrate per ton, or approximately 35 to 43 lb. of citric acid per ton.

ORANGE AND LEMON OILS IN CALIFORNIA

Four methods have been used in California for the recovery of the essential oils from cull oranges and lemons. These processes are (1) by pressure and centrifugal separation, (2) by steam distillation, (3) by removing the outer portions of the rinds by grating or "shaving" and pressing of the resulting rind, and (4) by extraction with petroleum ether.

By Pressure and Centrifugal Separation. The whole fruit is crushed and pressed in a continuous pressing device, the oil and juice are separated by means of a special high-speed centrifugal separator, and the crude oil is filtered through paper. Lemon oil is recovered in this manner as a by-product in the production of citric acid. The yield is relatively low.

The oil is usually lower in citral content than the imported oil because the juice dissolves an appreciable proportion of this ingredient. The Citromat juice extractor expresses the oil with the juice, and the oil is recovered by centrifuging. The Pipkin FMC extractor expresses the oil and juice separately, giving a good yield of both.

The orange juice may be used for canning, etc., or preparation of concentrate for freezing or sirup for soda-fountain and bottlers' use. The lemon juice is used for citric acid manufacture.

By Steam Distillation. The ground press cake from whole oranges or lemons, the gratings from mechanically peeled oranges or lemons, or the pressed whole fruit may be ground and distilled in a current of steam to

recover oil not removed by other means. The resulting oil is water-white and much inferior to the cold-pressed oil in color and flavor. It is also very unstable and rapidly deteriorates unless held in cold storage.

Steam distillation *in vacuo* yields an oil superior in flavor and keeping quality to that obtained by steam distillation at atmospheric pressure.

By Peeling and Pressing. Lemons and oranges may be peeled in a modified vegetable-peeling machine, such as is used in grating the peel off po-

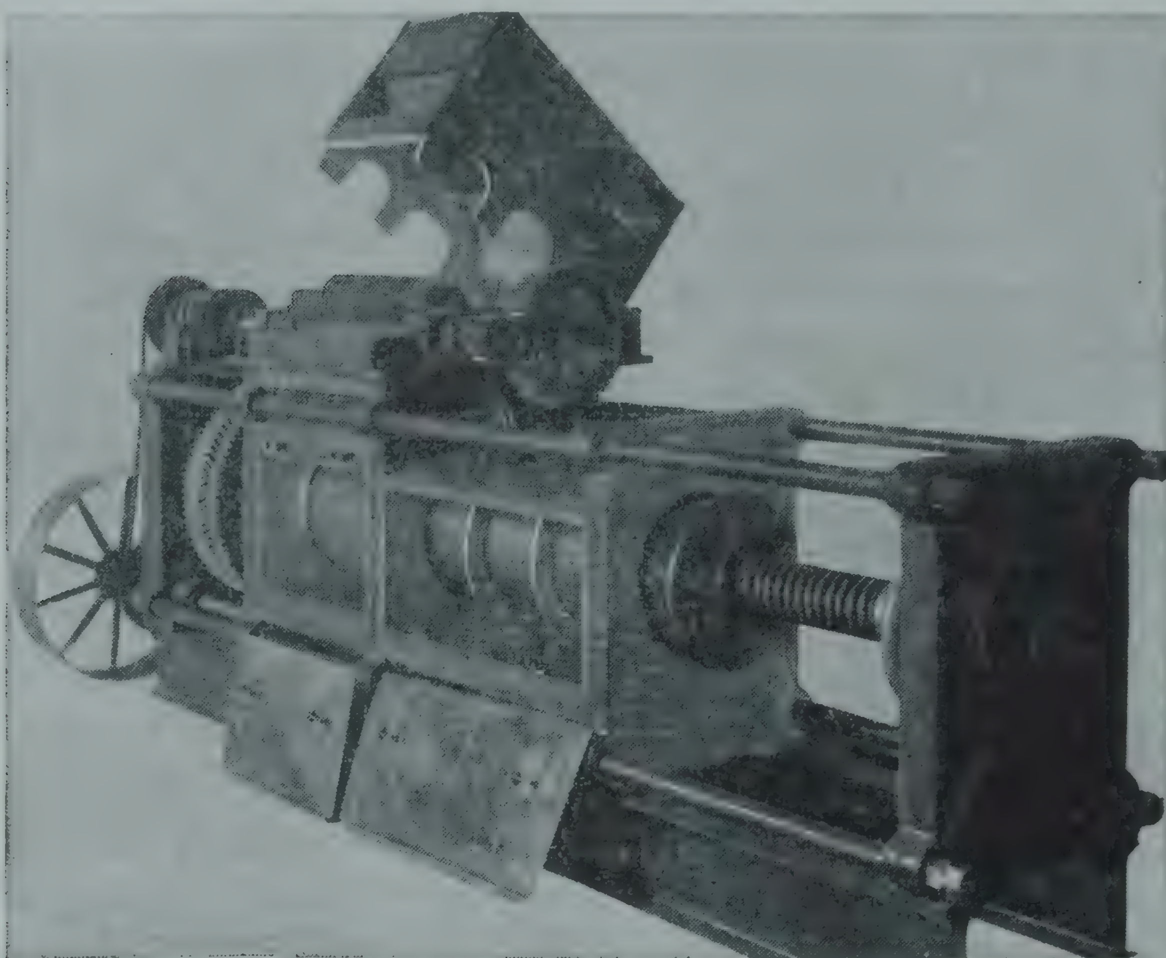


FIG. 108. Crusher and continuous press of type used for lemons for citric acid production. (*California Press Mfg. Co., San Francisco.*)

tatoes, which removes the outer portion of the rinds in the form of gratings; these may be pressed to obtain an oil of good quality. In the Citromat extractor the thin outer, oil-bearing skin may be removed as thin shavings from which the oil may be pressed. The press cake may be distilled in a current of steam to recover the remainder of the oil, which will be of poor flavor and poor keeping quality and should not be mixed with the cold-pressed oil.

By Pressing Peels and Centrifuging. The peels from the Brown juice extractor or other juicer may be finely ground or pressed, and the oil separated by centrifuging.

By Use of Solvents. At one time orange and lemon oils were prepared in Redlands, California, by first removing the outer portion of the peels by hand peeling and then recovering the oil by treatment of the peels with a volatile solvent. As it was found impossible to remove the solvent completely from the oil, the process was abandoned.

OTHER CITRUS BY-PRODUCTS

Numerous other citrus products and by-products are produced commercially in the United States and in European countries.

Marmalade. England imports from Spain large quantities of bitter so-called "Seville oranges," which are utilized in the preparation of marmalade. In California and Florida marmalade is produced commercially from citrus fruits (Chapter 14).

Marmalade Juice. It has been demonstrated by experiments at the University of California that the juice expressed from cooked citrus fruits and combined with the sliced peels can be sterilized in cans and shipped to marmalade factories or sold to housewives for the preparation of marmalade. It is believed that this product has commercial possibilities.

Citrus Fruit Juices and Sirups. Large quantities of oranges are used in juice stands for preparation of juice sold fresh to the consumer. Large amounts are also canned as described in Chapter 12, and large amounts are also utilized in producing concentrates, usually preserved by freezing (Chapters 13 and 25).

Vinegar. Orange juice normally contains 12 to 16 per cent of total soluble solids, of which about 9 to 13 per cent is sugars. If the juice is carefully fermented with a suitable yeast, it is possible to obtain fermented juices containing 4.5 to 6 per cent of alcohol by volume, which will yield vinegar above the legal limit of 4 per cent acetic acid (Chapter 21).

Dehydrated Citrus Products. Orange and lemon peels are dried in halves to a limited extent for use by extract manufacturers and bakers. The waste peels from juice production are coarsely ground, limed, pressed, and dehydrated. The juice from the peels is concentrated to a molasses and mixed with the dried peel. The mixture is used as stock feed.

The whole fruit may be sliced, dehydrated to bone dryness, and ground to a powder for use in flavoring bakery products.

Dried Juices. Lemon and orange juices may be dried to powders in spray-drying equipment in the same manner as milk if sufficient refined corn sirup, corn sugar, or milk sugar is added to prevent sticking and lumping. The drying *in vacuo* on a moving stainless-steel belt has been developed on an industrial scale. The basic procedure was pioneered by Strashun and others of the Western Regional Research Laboratory of the U.S.D.A. The Vacu-Dry Company, through a subsidiary company, is producing a dehydrated orange juice by this method in Florida, and the Thornton Canning Co. in California has installed continuous-vacuum-drying equipment for tomato products.

Pectin. Lemon and orange peels, waste products from the manufacture of juices, citric acid, and concentrates, are rich in pectin. C. P. Wilson and associates of the Exchange Lemon Products Company in 1925 developed a process of extracting and recovering pectin in powdered form from such

wastes. Their process has been improved and modified by the research laboratories of the above plant and of the California Fruit Growers' Exchange (details of the procedure are given in Chapter 14).

Candied Peels. Candied citron peel (peel of a citrus fruit, not a melon product) is a well-known article of commerce. The citron peels are fermented in sea water in Italy and other countries of the Mediterranean area and shipped in brine to the United States or elsewhere for conversion into candied peel. Some citron is also grown and brined in California. The brined peels are boiled in repeated changes of water to extract the salt and bitterness and to cook the flesh. The candying process is described in Chapter 15.

Some orange and lemon peel is brined in the United States and converted into candied products (Chapter 15).

Paste. At one time a paste was made from oranges for bakers' and confectioners' use by grinding the whole fruit, adding sugar, and concentrating to high sugar content in a vacuum pan. Another product consists of the finely ground oranges mixed with an equal weight of sugar and sterilized in cans. The fruit in both products must be cooked sufficiently to overcome toughness.

Confections. A very satisfactory candy has been made experimentally and on a commercial scale by cooking sliced whole oranges or lemons until soft, sieving the cooked fruit to give a purée, adding sugar, pectin, and corn sirup or invert sirup, and cooking to a stiff jelly. The jelly, after hardening on standing several hours or overnight, is cut into rectangular pieces and coated by rolling the pieces in coarse sugar (Chapter 15 for details).

Canned Citrus Fruits. The canning of grapefruit is described in Chapter 8. A canned saucelike product has also been prepared from grapefruit for use as a breakfast dish. Broken segments of grapefruit blend well with other fruits in canned fruit cocktail, fruits for salad, etc.

Oranges were at one time canned in slices or segments, but the flavor deteriorated after canning, and in so far as the author knows, the product is no longer on the market. However, Satsuma oranges in segments are canned successfully in Japan and exported to other countries, including the United States.

Wines, Brandies, and Cordials. Dry, as well as fortified, wines have been made commercially from oranges and grapefruit, as described in Cruess, "Principles and Practice of Wine Making." Brandies and cordials can also be made, the latter by adding brandy and sugar to the wines or the juices.

REFERENCES

(See also the references given at the end of Chap. 23 on several citrus products.)

Baier, W. E., and Wilson, C. W.: Citrus pectates: their properties, manufacture and uses, *Ind. Eng. Chem.*, **33**, 287, 1941.

Braverman, J. B. S.: "Citrus Products," Interscience Publishers, Inc., New York, 1949.

Chace, E. M.: By-products from citrus fruits, *U.S.D.A. Department Circ.* 232; revised 1942 as *Circ.* 577.

COLE, G. M.: Concentrates for lemonade, *Food Technol.*, **9**(1), 38–45, 1955.

CRUESS, W. V.: "Principles and Practice of Wine Making," Avi Publishing Co., New York, 1947.

——— and GLICKSON, D.: Observations on the brining and candying of citron, *Fruit Products J.*, **12**, 17, 1932.

——— and SINGH, L.: Marmalade juice and jelly juice from citrus fruits, *Univ. Calif. Agr. Expt. Sta. Circ.* 243, 1923.

The essential oils and allied industry of Italy, *Perfumery Essent. Oil Record*, **13**, 198–213, July 12, 1922.

FELLERS, C. R.: Chemical studies and fermentation studies on citron, *J. Agr. Research*, **53**(11), 859–867, 1936.

HAVIGHORST, C. R.: How orange products are made, *Food Inds.*, **17**, 1022–1027, September, 1945.

HEID, J. L.: Citrus products research problems, *Fruit Products J.*, **25**(3), 77–81, November, 1945.

———: Drying citrus cannery wastes and disposing of effluents, *Food Inds.*, **17**, 1479, 1945.

HOLTON, H. H., and HAVIGHORST, C. R.: Citric acid from lemons, *Food Eng.*, **25**(6), 58–60, 175, 177, 162–175, June, 1953.

MCCULLOCH, L.: Curing and preserving citron, *U.S. Dept. Agr. Circ.* 13, 1927.

MCNAIR, J. B.: Citrus products, *Field Museum Nat. History, Botan. Ser., Pub.* 238, 1926. 2 vols.

MOORE, E. L.: Concentrating and drying citrus juices, *Proc. Inst. Food Technol.*, 1945, pp. 160–168.

NEAL, N. M., BECKER, R. B., and ARNOLD, P. T. D.: The feeding value of citrus by-products, *Florida Agr. Expt. Sta. Bull.* 275, 1935.

NELSON, E. K., and MOTTERN, H. H.: Florida grapefruit oil, *Ind. Eng. Chem.*, **26**, 634–637, 1934.

POORE, H. D.: Analyses and composition of California lemon and orange oils, *U.S. Dept. Agr. Tech. Bull.* 241, 1932.

———: Citrus pectin, *U.S. Dept. Agr. Dept. Bull.* 1323, 1926.

POWELL, G. H., and CHACE, E. M.: Italian lemons and their by-products, *U.S. Dept. Agr., Bur. Plant Ind., Bull.* 160, 1909.

REGAN, W. M., and MEAD, S. W.: The value of orange pulp for milk production, *Univ. Calif. Agr. Expt. Sta. Bull.* 427, 1927.

SCOTT, W. C., and HEID, J. L.: Marmalade stock and marmalade, *Texas Citriculture*, **9**, 18, 1934.

SUCHARIPA, R.: "Die Pektinstoffe," Serger and Hempel, Brunswick (Braunschweig), Germany, 1937.

VON LOESECKE, H. W.: A review of the information on mycological citric acid production, *Chem. Eng. News*, 1945, p. 1952.

———, MOTTERN, H. H., and PULLEY, G. N.: Wines, brandies and cordials from citrus fruits, *Ind. Eng. Chem.*, **28**, 1224–1229, 1936.

WARNEFORD, F. H. S., and HARDY, F.: Manufacture of calcium citrate and citric acid from lime juice, *Ind. Eng. Chem.*, **17**, 1283, 1925.

WILSON, C. P.: "California Citrus Oils," California Fruit Growers' Exchange, Products Department, 1933.

———: Relation of chemistry to the citrus products industry, *Ind. Eng. Chem.*, **20**, 1302–1307, 1928.

———: The manufacture of pectin, *Ind. Eng. Chem.*, **17**, 1065–1067, 1925.

———: The manufacture of citric acid, *Calif. Citrograph*, February, 1921, pp. 110, 129.

Also *Ind. Eng. Chem.*, **13**(6), 554, June, 1921.

CHAPTER 25

FROZEN-PACK FRUITS AND VEGETABLES

Meats and fish as well as poultry have been frozen and distributed in that condition for many years. About 1907 the barreling and freezing of berries on the Pacific Coast became commercially important. Some other fruits such as apricots, plums, and peaches were also frozen in barrels, but the principal pack was of strawberries, raspberries, and blackberries. During the twenties small amounts of berries were also frozen in small containers for the retail trade, the berries usually being packed with 1 part of dry sugar to 3, 4, or 5 parts of fruit. About 1928 to 1930 frozen fresh vegetables were placed on the market in small containers for the retail trade, although as they were raw (not blanched), losses through deterioration in flavor were severe. With the advent of blanching this difficulty was overcome.

The freezing of fruits and vegetables for the retail trade has now attained important proportions, as evidenced by the following figures from *Quick Frozen Foods,* June, 1956 (data for 1955, 1956, *Western Canner and Packer*):

For the years 1942, 1945, 1950, 1953, 1955, 1956, the United States packs of frozen vegetables were 152,512,470 lb., 307,977,360 lb., 587,101,000 lb., 1,103,269,000 lb., 1,139,700,000 lb. and 1,533,000,000 lb. respectively. The corresponding packs of frozen fruits were, for these same years, 194,644,923 lb., 430,176,545 lb., 472,173,000 lb., 541,960,641 lb., 659,800,000 lb., and 694,300,000 lb. respectively.

These products more nearly resemble the fresh in appearance and flavor than they do the canned. They are known in the trade and in the home as "frosted foods," "frozen foods," "frozen-pack foods," or "quick-frozen foods," and the process is termed "preservation freezing," "quick freezing," or merely "freezing."

Not All Varieties Equally Suitable. Peas, string beans, corn, broccoli, spinach, asparagus, sprouts, and Lima beans are examples of vegetables that freeze very successfully. Tomatoes and cabbage are examples of vegetables that do not respond well to freezing preservation.

Fruits exhibit similar differences. Peaches, apricots, berries, pineapple, apples, and grapefruit respond well to freezing; bananas, avocados, sliced persimmons, and Concord grapes are not so satisfactory. Within a given

kind of fruit or vegetable, different varieties, as of peaches, often differ markedly in their suitability for freezing.

Distribution Being Solved. At the time of the first revision of this book (1938) facilities for the retail distribution of frozen foods were lagging far behind production capacity; the retail outlet was the bottleneck because of lack of suitable freezer cabinets in the retail stores. This difficulty has been met by installation in grocery stores of greatly improved frozen-food dispensing cabinets, from which the customer may select the cartons of frozen fruits, vegetables, or precooked foods that strike her fancy.

In spite of the relatively high prices, housewives are buying these products in large volume—very often in preference to the fresh products, such as peas, available at the time of purchase.

Frozen Foods Perishable. The preparation of fruits and vegetables for freezing and the freezing do not render the products sterile. Consequently on thawing they spoil even more quickly than the raw fresh products in their natural state. Some consumers learn this elemental fact by sad experience; others read the label, which usually warns that the food should be used promptly and not held after thawing.

Relation of Processor to Warehouse. At present many producers of frozen foods in California prepare and pack them in their own establishments but do not store them on their own premises. Instead the packed products are taken at once to quick freezers, usually located in a nearby cold-storage warehouse. Here they are frozen and then stored in the warehouse's adjacent freezing-storage rooms. Some of the larger freezers operate their own freezing-storage warehouses.

Physical Changes Occurring during Freezing and Thawing. The purpose of freezing storage is to retain to as great a degree as possible the properties of the fresh fruit, vegetable, or other food product. However, during freezing and thawing certain irreversible changes occur that render the frozen and thawed product quite different from the fresh in texture and general appearance. There is usually considerable collapse of the tissues on thawing; the thawed product usually is rather limp, and considerable liquid is usually lost from the tissues as "drip liquid" on thawing and draining. The extent of these changes varies greatly with the character of the product. Thus some starchy vegetables such as peas, shelled green beans, and corn change relatively much less than certain other products such as tomatoes, lettuce, and cantaloupe. The starch evidently gives additional support to the cells.

Woodroof (*Georgia Agricultural Experiment Station Bulletin* 168) has given a good summary of the changes that occur and the various theories offered in explanation thereof. He states that flabbiness is due to breaking down of the contents of the cells which formerly gave support to their walls. The loss of plant juices is not due to rupturing of the cell walls, but, he

believes, to irreversible precipitation of cell contents liberating "bound water" and also water which was previously present in the vacuole; this water is not reabsorbed on thawing. He found that the amount of water lost through cell leakage is very similar to that lost by leakage in cooking, by placing the tissue in saturated salt or sugar solution, or in desiccation. Woodroof calls attention to the fact that tissues having very thick cell walls do not show as marked changes as those with thinner cell walls, owing to the fact that support of the tissues is largely maintained by the cell walls.

Various theories have been offered in explanation of the changes observed in plant and animal tissues on freezing and thawing. Classen believed that the injury was caused by puncturing of the cell walls by ice crystals. Sommerville in England and Sachs in Germany thought injury was due to too rapid thawing. Chandler, Maximov, Mollard, Matruchat, and Molisch independently have put forward the theory that injury is not due to cold directly but to ice formation. Desiccation by withdrawal of water into the intracellular spaces to form ice causes death of the cell; the plasma membrane is destroyed, and plasmolysis occurs. Maximov believed the actual injury was caused by changes in the plasma colloids during ice formation. Chandler sums up the ice-formation theory by saying, "There can be no injury by cold without ice formation." A modification of the preceding theory is that death of the cell is caused by salting out of the protein fraction of the protoplasm owing to high salt concentration induced by withdrawal of water; the protoplasmic gel is thus destroyed. Another theory attributes death of the cell to precipitation of proteins owing to increase in hydrogen-ion concentration. Still another theory holds that injury to the protoplasm by cold is occasioned by increase in viscosity of the protoplasm beyond the point where it can function.

Woodroof and also Joslyn and Marsh favor the ice-formation theory of Chandler, Maximov, and the other investigators mentioned in the preceding paragraph. It appears to be the theory best supported by evidence and scientific opinion.

Freezing disorganizes the tissues, renders them permeable, and liberates enzymes. Consequently during thawing, certain enzymes, particularly oxidizing enzymes, often cause serious changes. Sliced fresh peaches, apricots, and pears darken very rapidly on thawing owing to oxidasic browning. For this reason such products may require treatment with sulfur dioxide, packing in sirups containing ascorbic acid, or blanching to retard or inactivate oxidizing enzymes.

The extent of the physical changes occurring during freezing and thawing of fruits and vegetables was extensively studied by Joslyn and Marsh (*University of California Agricultural Experiment Station Bulletin* 551, 1933). They gave particular attention to the "drip loss" on thawing, i.e., the loss in weight due to exuding and dripping away of tissue juices during draining

of the thawed products for 24 hr., as affected by rapidity of freezing, composition of the liquid surrounding the product while frozen, and other factors. Strawberries, packed with various proportions of dry sugar to fruit, lost from 19.4 to 44.2 per cent in weight on thawing after freezing storage of several months. Apricots lost 2 to 13.6 per cent. When packed in sirups, the losses were lower, although in several individual instances heavy loss in weight on draining occurred.

They observed that fruits and vegetables frozen quickly in carbon dioxide "snow" lost less liquid on thawing than when frozen at 0°F. in air. Thus peas frozen at 0°F. in air lost 8.4 per cent in weight on thawing, and those frozen in carbon dioxide snow at −100°F. lost 4.5 per cent. The figures for asparagus were 23.4 and 19.2 per cent; for string beans 14.5 and 8.2 per cent; strawberries 37.1 and 29.7 per cent; and apples, sliced, 1.03 and 0 per cent loss. Woodroof gives additional data for fruits, indicating a somewhat smaller drip loss from fruits frozen in carbon dioxide snow ("dry ice") than those frozen slowly in air, presumably at 0°F. However, on subsequent cooking of frozen-pack vegetables, there was little to no observable difference between the slow- and the quick-frozen products. Some vegetables blanched and packed in dilute brine before freezing actually gained in weight on thawing in Joslyn and Marsh's experiments.

Another change that occurs on freezing is expansion in volume. Whole fruits often burst on freezing; the same is true of shelled Lima beans. Barrels or glass jars of frozen-pack juices, crushed fruits, and other liquid or semiliquid products must not be filled completely, else they may be burst by expansion of the contents on freezing. Joslyn and Marsh give the following increases in volume on freezing at 0 to 5°F.: water, 8.6 per cent; 20 per cent cane-sugar sirup, 8.2 per cent; 40 per cent sirup, 5.2 per cent; 50 per cent sirup, 3.9 per cent; and 60 per cent sirup, no increase in volume.

Chemical and Enzymatic Changes. Changes in color, flavor, texture, and odor of food products induced by enzyme action and by chemical change may occur before and during freezing, during storage, during thawing, and after thawing.

Certain fruits are prone to turn brown because of action of oxidizing enzymes plus atmospheric oxygen; this change is particularly rapid during and after thawing. Such fruits, packed without sirup, brown severely in freezing storage when stored in containers that are not airtight. Light treatment with dilute sulfur dioxide solution prevents such changes. However, the addition of a small amount of ascorbic acid to the sirup in which the fruit is packed is now the customary method of preventing darkening and loss in flavor.

Berries and some other fruits, stored without sirup in containers that admit air gradually, deteriorate in flavor, odor, and color, the deterioration being more rapid at temperatures of 20 to 25°F. than at −5 to 10°F. Such

fruits cannot be treated with sulfur dioxide or blanched without completely changing their character. Probably enzymes are involved.

Unblanched and also underblanched vegetables deteriorate rapidly in color, flavor, and odor even when stored at −5°F. They develop a haylike odor and flavor, and their initial green color changes toward the yellow, eventually becoming yellow when later cooked for eating. These changes have been definitely proved by Joslyn and Marsh and by Diehl and his associates to be due to enzyme action. Undoubtedly some of the deterioration is oxidative in nature, but it is equally probable that other enzymes than the oxidases are also involved.

Diehl and associates thought that catalase activity, judged qualitatively by addition of hydrogen peroxide to a crushed sample of the blanched vegetable, was a rough index of the amount of deterioration to be expected during storage. Thus, when peas and certain other vegetables were blanched sufficiently in steam or hot water to inactivate catalase, they could be expected to keep reasonably well.

Subsequently, however, Arighi, Joslyn, and Marsh found that considerably higher temperatures or considerably longer periods at lower temperatures than required to inactivate catalase were required to prevent undesirable changes during freezing storage of peas and spinach grown in California. They used a storage temperature of 0°F. They found also that the acetaldehyde content of the blanched peas closely paralleled their keeping quality but that no such relationship existed with spinach. They reported that peas blanched 2 min. at 60°C. (140°F.) contained a fairly active catalase and deteriorated severely in flavor and color; those blanched 2 min. at 65°C. (149°F.) were free of catalase, but they nevertheless deteriorated markedly in color and flavor; the same was true of those blanched 2 min. at 67.5°C. (153.5°F.). Those blanched 2 min. at 70 and 75°C. (158 and 167°F.) were free of catalase but somewhat inferior in flavor and color, after freezing storage, to those blanched at 77.5°C. (171.5°F.). The best quality was attained at 80 and 85°C. (176 and 185°F.). At 90°C. (194°F.) the texture was too soft and the skins were rather tough; these defects were more evident at 95 and 100°C., evidently owing to overcooking. In plants in eastern Oregon and Washington visited in 1955 peas were blanched in water at about 200°F., in some cases long enough to inactivate catalase only, but in at least one plant sufficient to kill peroxidase also.

Recently the author found that many samples of commercially packed frozen vegetables on the retail market, showing a negative catalase but positive peroxidase reaction, had developed off, haylike flavors and odors. It is recommended that blanching be sufficient to destroy peroxidase.

Vegetables even when heavily blanched to destroy all enzymes lose their green color and acquire disagreeable odors and flavors when stored for a long period in freezing storage in containers that admit air freely. Evidently in this instance simple oxidation is involved.

There is evidence that pectic enzymes of berries cause some hydrolysis of pectin. Invertase is also active during and after thawing, causing inversion of sucrose.

Microbiology of Frozen Foods. Microorganisms are of concern to frozen-food packers and consumers for two reasons: they may cause deterioration in quality and even complete spoilage, or they may render the food dangerous to health.

If one considers the first of these roles, it may be stated that organisms may develop before the product has become frozen; a few forms are able to develop in freezing storage at certain temperatures; and they may grow in the product after thawing. In California in the early days of freezing storage, considerable spinach packed hot in large fiberboard boxes spoiled before it attained freezing temperature. Although the containers had been placed at a freezing temperature, cold penetration was so slow in the large masses of solid-pack blanched leaves that microorganisms multiplied and caused spoilage before the centers of the packages attained a temperature that would inhibit growth. In order to prevent such spoilage, the product should be frozen in shallow trays or at least chilled nearly to freezing before packing in large containers, or it should be packed in small containers. It is also essential that the packages, even small ones, be stacked in the freezing tunnel in such a manner that air can circulate freely between them, or they should be frozen in some form of plate-type quick freezer.

Peas deteriorate rapidly after shelling if allowed to stand too long before blanching and freezing. Spoilage can also occur rather rapidly after blanching if the peas are allowed to stand for a protracted period at room temperature.

At one time it was generally assumed that there was no multiplication of microorganisms in frozen foods and that, as long as the product remained frozen, deterioration through microbial activity could not occur. However, Berry reports growth of a *Cladosporium* species at −2°C. (28.4°F.); of an *Oïdium* species and of a Torula yeast at −4°C. (24.8°F.). Tanner states that there is some evidence that certain psychrophilic bacteria may grow at −10 to −20°C. (14 to −4°F.). In this connection Diehl, Pentzer, Berry, and Asbury state that certain molds may grow slowly at about −6.6°C. (20°F.) and some bacteria at −4°C. (25°F.). They recommend that storage temperatures much in excess of 15°F. (−9.5°C.) should not be employed. Also the lower the storage temperature, the slower is deterioration caused by enzyme activity and chemical change. At present, 0°F. or lower temperatures are customary for storage of frozen foods.

A great deal of research has been conducted on the problem of effect of freezing storage on *Clostridium botulinum*, typhoid bacilli, cholera bacilli, and on other toxic or disease-producing bacteria. In general, freezing kills many, but not all, of these organisms. In fact, freezing storage preserves many of them, just as it preserves the food product. Data have been re-

ported showing that molds, yeasts, and bacteria have lived for several years in frozen foods. They appear to survive better at the lowest temperatures used than at temperatures only slightly below freezing.

Wallace and Park found that the spores and the toxin of *Cl. botulinum* survived freezing storage with no appreciable injury for at least 1 year; Straka and James obtained similar results.

Tanner cites an outbreak of typhoid at Jassy, Romania, as reported by Lascu, from ice frozen for 8 months. It has been found that typhoid bacilli will live in ice cream for more than 2 years. Wallace and Crouch found that a number of other pathogenic bacteria also survive for long periods in ice cream.

These various findings prove that pathogenic bacteria, if present in the food product, can survive freezing storage and, if the product is consumed without further cooking, can infect the consumer.

Cl. botulinum does not grow and produce toxin during freezing storage; but if the foods infected with it are allowed to thaw and to stand at room temperature for a sufficient time, toxin formation may ensue. Wallace and Park inoculated cherries, strawberries, raspberries, string beans, carrots, and peas with detoxified spores of *Cl. botulinum;* stored them at −16°C. (3.2°F.) for 2 weeks to 12 months; at intervals removed containers of the frozen products; allowed them to stand 3, 6, and 10 days; and fed small amounts to guinea pigs. The cherries remained nontoxic; toxin was produced once in strawberries and twice in raspberries. Toxin was produced in a number of samples of each of the vegetables; in several cases in 3 days' storage at room temperature. Also some of the samples of vegetables remained nontoxic even after 10 days at room temperature.

In commercial practice contamination with the spores of this organism would be much lower than in the samples heavily inoculated by Wallace and Park or by Straka and James, and probably in most cases the organism would be absent. Nevertheless, there is possibly a real danger in allowing frozen vegetables to thaw and stand several days before use. In one case observed in San Francisco frozen-pack peas delivered to a restaurant were reported spoiled and unfit for food. Investigation by Marsh and Joslyn showed that the delivery company had allowed the frozen peas received by it from the cold-storage warehouse to thaw and stand several days; the peas were then again frozen and delivered to the restaurant. Needless to say, the product was completely spoiled.

It is therefore essential to maintain frozen-pack foods in the frozen state until received by the consumer, who in turn must use them very soon after thawing.

On the other hand, since frozen-pack vegetables are, or at least should be, cooked before serving, the health hazard is at most remote.

Diehl and associates found in some cases considerable increase in num-

bers of yeast cells in frozen-pack berries in 50-gal. barrels, due to extremely slow cooling of the berries near the center of the container. They recommend precooling of the berries and sugar at about 32°F. before packing and also the establishment of maximum limits for numbers of yeast cells and mold present in frozen-pack fruits, as determined by the general Howard technique. Both recommendations are very worthy ones.

Containers. Unless protected by wrapping or packaging, most frozen foods deteriorate very rapidly, becoming unsightly and unpalatable. Moisture transmission rate of a satisfactory package must be slow, as desiccation is a major cause of loss in quality in frozen foods.

It has been found that adverse chemical, physical, and enzymatic changes proceed at a slower rate in the frozen products when packed in hermetically sealed airtight containers. In this regard the vacuum-sealed container is superior to that sealed in air. Hermetically sealed cans of 6-oz. size for retail sale and larger for institutional use are used to the practical exclusion of other containers for frozen concentrates. Enamel-lined tin cans for berries and other colored fruits are preferable to plain tin since they affect the color less. Key-opener enamel-lined cans holding about 1 lb. of berries and sugar were used successfully in the Pacific Northwest at one time. They were sealed under vacuum. The principal objection to the airtight container is the danger that the consumer will assume that the contents is nonperishable and may on that account allow the product to stand at room temperature with resulting spoilage. If the product is a nonacid vegetable, it may under such conditions become toxic. However, if the can bears on the label in large type some such advice as "Perishable—use at once after thawing" there should be little danger in using such containers. Large friction-top enamel-lined containers such as those used for frozen eggs are suitable for packing frozen-pack fruits and vegetables for use by preservers, hotels, and other large consumers. These cans, usually of 30 lb. capacity, are commonly used for broken eggs preserved by freezing. Small friction cans are also available for the household trade. Since they are nearly airtight, they prevent absorption of off odors and flavors and because of their convenience are rather highly recommended for frozen-pack foods.

Paraffined cardboard cups and "tubs" are in common use for frozen-pack foods and have proved fairly satisfactory, particularly for certain precooked foods and those packed in brine or sirup. The covers slip into a groove near the top of the containers in some styles, and in others the top is crimped into place by rolls in much the same manner as in the sealing of tin cans. They are inexpensive, convenient, and light in weight.

A satisfactory package, in addition to having a slow vapor-transmission rate, should tend to exclude air and thus minimize oxidation; should protect the food against dirt and other contamination; and should be attractive in appearance. It should be of such shape that it will use a minimum of space

FIG. 109. Types of frozen-food retail-size containers. *Left to right:* Regular-size overwrapped carton; "thin" style overwrapped carton; overwrapped regular-size fiber can; small-size fiber can, not overwrapped; 6-oz. fruit-concentrate can.

in the retail frozen-food dispensing cabinet, a package of rectangular shape being most efficient in that respect. It should be tough and strong enough to resist breakage or puncturing by the rough handling received in retail sales cabinets. The cost should be low. It must be waterproof (leakproof), as many products are packed in a sirup or sauce, or if packed with dry sugar, a sirup forms by osmosis. It should not impart any undesirable odor or flavor to the food. It should not absorb water and thereby become structurally weak and soft. It should lend itself to automatic handling by machine, filling of certain products by machine, and, if a carton, to overwrapping by machine.

Rectangular, retail-size, paperboard containers are of several types and capacities and usually are shipped to the freezing plant in the knocked-down (flat) condition. Some styles are opened by hand at the filling station, and some are opened and formed by machine. The trend appears to be toward greater use of the latter type. A widely used carton is the Marathon Corporation's paperboard container, style No. 5. It does not require an inner plastic bag, since a moisture-vapor-proof liner is laminated to the inner walls of the carton. It has an attached cover that may be folded down into place by hand or by machine after filling.

Some cartons make use of an inner pliofilm, cellophane, polyester, or other plastic-film bag. The open end of the bag is heat-sealed by an electrically heated device after the bag is filled. The plastic should not only be moisture-vapor-resistant and tough, but should also not become brittle and fragile at freezing temperatures. It should, of course, also be free of objectionable odor or flavor.

Retail-size cartons are of end-filling and of top-filling types. The former are satisfactory for free-flowing foods such as peas and whole-kernel corn,

while the top-filling type is more easily packed with such products as asparagus spears, halved apricots or peaches, and broccoli heads.

Cartons made of aluminum foil are in use for certain products, particularly some precooked foods. However, some products will corrode and perforate the foil, e.g., some Chinese foods packed in sauces. Therefore, if the use of an aluminum-foil package is contemplated, storage tests should first be made to ascertain whether or not the foil will be corroded or perforated by the food to be packed in it. Lithographed aluminum foil used as an overwrap for filled paperboard cartons has proven very satisfactory. Precooked products such as meat pies, stews, and fruit pies are often packed in aluminum pie tins or divided plates, and these in turn in shallow, overwrapped cartons.

A container extensively used for strawberries and some other products is the rectangular fiber can. The body is of water-vapor-proofed paperboard with an inner waterproof lining laminated to the walls. The ends are of enameled tin plate. The bottom is attached by the manufacturer. After filling with the fruit or other product, the top is sealed on by a machine resembling a double seamer for all-metal cans. The well-known Sefton fiber can is of this type, and similar "cans" are made by leading can manufacturers.

Capacities of the various types of retail containers vary. As previously mentioned, the small cans used for 3-to-1 fruit concentrates are of 6-oz. capacity for the retail trade. Cartons for fruits and vegetables are often of 10-oz. net-contents capacity, a size that has largely replaced the 16- and 12-oz. sizes. For the institutional trade (restaurants, hotels, hospitals, etc., and the military) containers are of large sizes, such as 5-, 10-, and 25-lb. cartons, No. 10 cans, 30-lb. egg tins, and others. For commercial producers of jams, jellies, and preserves 50-gallon size metal drums lined with protective enamel or plastic, or 50-gallon size wooden barrels are often used. See Chapters 14 and 15.

Peas and other vegetables have been packed also in 25- to 30-lb. fiberboard boxes lined with plastic-film bags, the vegetables being first frozen in air in a sharp freezing room or rapid freezer and packed in frozen condition without liquid in the boxes, which are sealed and stored at once at or below 0°F.

Multiwalled laminated paper bags lined with plastic film and holding 40 to 50 lb. of diced carrots or other products are often used for temporary freezing storage, for repacking later with peas or alone in retail-size packages, or for shipment to soup manufacturers or other large users.

Theoretically, the vacuum-sealed airtight tin container is preferable to paper-container cartons, friction-top cans, and other containers that admit air to the product and permit evaporation of moisture from it. For many products the "not-airtight" containers are quite satisfactory, particularly

if after they are packed in lined, tightly sealed cases. There is then less tendency for evaporation of moisture and much less opportunity for absorption of cold-storage odors and flavors.

In the Pacific Northwest most of the berries for bakers' and preservers' use were formerly packed in paraffin-lined spruce barrels of various sizes, the 50-gal. size predominating. Berries usually are packed in these with dry sugar. One of the objections to these containers is the slow freezing of the contents, due to the slow penetration of heat or cold through the wood and to the great distance to the center of the container. Hence the berries are often at a temperature that will permit growth of yeasts or molds for 24 hr. or longer. A second objection is that once the barrel of berries is opened, the contents must be used soon, since the berries near the surface in the opened barrel rapidly deteriorate in flavor and color through oxidation.

Both types (end-fill and top-fill) of retail cartons, after they are filled and the lid is folded in place, are overwrapped by automatic wrapping machine, which cuts a piece of lithographed waxed paper, cellophane, or aluminum foil from a large roll and automatically folds it around the package and heat-seals it in successive rapid motions.

Some plants fill the packages by hand, but automatic filling machines are now available and in process of being improved. Peas, Lima beans, cut corn, cut asparagus, and some other products can be filled by machine; others such as spinach, asparagus stalks, and broccoli stalks are best filled by hand. Such products as soups, sieved foods, sauces, and fruit juices lend themselves very well to automatic filling. In addition to folded cartons, paraffined cups and other rigid containers are in use. Among these is the well-known Lily Tulip cup. Some of the rigid cardboard containers are of rectangular shape for better use of storage space.

For acid foods such as fruit juices, tomato sauce, catsup, and others, hermetic containers such as tin cans and glass bottles or glass jars may be used. Their use for nonacid foods such as vegetables and precooked foods in general is not common at present, because of cost.

Recent investigations have established adequate precautionary measures which make the hermetic container safe for nonacid foods.

Progress is being made on coating paperboard and fiberboard containers for the military with a thermoplastic wax after the food is packaged. An aluminum-foil overwrap greatly reduces moisture loss, as do also pliofilm and other moisture-resistant plastic-sheet materials used as inner liners or bags inside cartons or as overwraps.

For the institutional trade (bakers, jam manufacturers, hospitals, ships, restaurants, hotels, etc.), large cellophane-lined cartons are in use. Instead of attached plastic linings, large plastic bags are also used in such cartons. Friction-top 30-lb. tins are also commonly employed, particularly for berries and other soft fruits used by jam makers.

Blanching (Scalding). At present most fruits for frozen pack are not blanched before freezing. Berries would soften badly, and blanching is probably of no value for them. On the other hand, sliced or halved peaches, pears, and apricots and sliced or quartered apples are sometimes blanched to inactivate oxidizing enzymes, since blanching would inhibit browning and development of undesirable flavors, particularly during and subsequent to thawing.

All vegetables for frozen pack, with the possible exception of rhubarb, should be blanched before freezing in order to inactivate enzymes that cause undesirable changes in odor, taste, and color. As stated in the section on enzymes, unblanched vegetables acquire during freezing storage a disagreeable haylike odor and flavor and deteriorate in color; also some unblanched vegetables become tough in storage. As mentioned elsewhere, Diehl and associates have stated that if blanching is sufficient to destroy catalase, the vegetables will keep satisfactorily in freezing storage. Joslyn, Marsh, and Arighi, however, are convinced from their experiments, particularly with peas and spinach, that a considerably more severe blanching is necessary, because other enzymes responsible for undesirable changes are considerably more difficult to inactivate by heat than is catalase.

Smart and Brunstetter found that blanching of Lima beans at 212°F. for 3 min. gave a more satisfactory product than blanching a longer or shorter period at 212°F. or blanching at 190°F.

Probably, for average commercial conditions, blanching at the boiling point either in steam or in boiling water will prove more practicable than blanching at lower temperatures. However, blanching in water at 200°F. is in common use for peas and some other vegetables with satisfactory results. Since steam removes less of the water-soluble materials than does water, it should be recommended in preference to boiling water for vegetables to be packed without liquid. The period of heating will vary considerably with the kind of vegetable and its previous preparation; thus corn on the cob will require a much longer period than peas (see directions for the individual vegetables). It should be sufficient to completely destroy peroxidase in most vegetables.

In addition to inhibiting enzyme action and thus stabilizing odor, flavor, and color, blanching wilts the vegetable and decreases its volume so that it may be packed more conveniently and efficiently. Blanching, including losses of vitamins and other nutrients, is fully discussed in Chapter 3.

Packing with and without Liquid. At present considerably more fruits and vegetables are packed without sirup or brine than with these liquids, although the packing of fruit in sirup is common practice for sliced peaches and apricots. Strawberries are usually packed with dry sugar. Experiments conducted at the University of California in 1918 by Overholser, Bjarnason, and the author and repeated on a more extensive scale later by Joslyn,

Marsh, and others showed that berries and other fruits retain their color, flavor, and texture better when packed in sirup than when packed with sugar or with no addition.

The University of California Food Technology Laboratory experiments have shown that for fruits that darken rapidly, such as apricots, white grapes, peaches, and pears, the addition of sirup containing ascorbic acid is practically necessary. The darkening can also be prevented by use of sulfur dioxide or preliminary blanching. Berries, however, behave quite satisfactorily when packed with dry sugar. Peas, asparagus, broccoli, sprouts, cauliflower, Lima beans, corn, spinach, and string beans are satisfactory packed dry without liquid, although Diehl and associates of the U.S.D.A. and Joslyn and Marsh of the University of California laboratory have found the quality to be somewhat better when frozen in 2 per cent salt brine.

Commercial handlers and large users of frozen-pack foods as well as housewives prefer the dry pack because of its lower weight and convenience; it is not necessary to thaw a large, solidly frozen mass. The dry-pack products are much more easily removed from the containers. The shipping weight is, of course, also much lower. In general, however, they deteriorate more rapidly in storage than do the same foods packed in sirup or brine.

Some products, such as avocado flesh for use in ice cream, persimmon for fountain and ice-cream use, and certain other soft fruits are most satisfactory for freezing storage when puréed or crushed and mixed with the requisite amount of sugar before freezing.

The practice of some packers of adding 1 part by weight of 60 to 70° Brix sirup to 3 or 4 parts of fruit is unsatisfactory because it leaves one-third to one-half of the fruit uncovered and oxidation ensues.

The procedure will vary with the product, the demands of the trade, and to a great extent the preference of the packer.

Rates of Cooling and Freezing. Diehl, Magness, Gross, and Bonney determined the rates of cooling of berries packed with sugar under practical industrial conditions in the Pacific Northwest. Resistance thermometers were inserted to the center of the containers; they were also inserted 4 to 6 in. from the bottom and 4 to 6 in. from the top after the barrels were filled. Naturally, cooling was more rapid in the latter two positions than at the center. In one experiment the freezing room was at 14°F.; Marshall strawberries were packed with dry sugar as a 2-plus-1 pack, i.e., 2 lb. of berries to 1 of sugar, in a 50-gal. barrel, the berries and sugar being at about 61°F. when packed. Nine hours elapsed before any cooling occurred at the center of the barrel. At 24 hr. the temperature at the center was 53°F.; at 48 hr. it was 42°F.; and at 72 hr., 34°F. These conditions would have been considered very favorable for commercial packing of

berries, yet the fruit was at a temperature favorable to the growth of yeast for more than 48 hr.

In another experiment 50 gal. of 2-plus-1 Marshall strawberries was placed in rooms at 0., 15., and 30°F. At 0°F. the center of the barrel reached 40°F. in 1½ days; at 15°F. in 2 days; and at 30°F. in 3½ days. Similar results were obtained with other varieties of berries. Even at 0°F. the berries remained for over 1½ days at temperatures that would permit yeast growth and fermentation.

Because of the very slow cooling in these large barrels with considerable resultant spoiling, it has been customary to place a block of ice in the center of the barrel of berries. While this hastens cooling, it dilutes the pack, and the addition of ice must be declared on the label.

Accordingly, in several of Diehl's experiments, berries were precooled in shallow crates at 32 to 34°F. for 18 hr., removed, and packed with sugar in 50-gal. barrels as a 2-plus-1 pack. The contents of the barrels were at 36 to 42°F. when rolled to the freezing room, as compared with 60 to 70°F. for berries packed without precooling. Consequently the precooled berries were at a much more favorable temperature to resist fermentation. About 2½ days' cooling at 15°F. was required to chill the contents of the nonprecooled barrel to the initial temperature of the precooled fruit. Therefore it can be seen that precooling should be used for berries to be barreled, although most plants are not well prepared to conduct the extra operation. This practice would prevent practically all danger of condemnation of barreled berries by state or Federal food authorities on the basis of high yeast count.

Joslyn and Marsh (*University of California Agricultural Experiment Station Bulletin* 551) made numerous measurements upon the rate of cooling of various food products in various sizes and types of containers, using thermocouples placed at approximately the centers of containers and connected to a sensitive potentiometer in order to follow temperature changes. One interesting finding was that cane sugar cooled more rapidly than did water and continued cooling without interruption until the temperature of the freezing room (about 4°F.) was attained. Water and light sirups cooled steadily until they began to freeze, then remained at a constant temperature in No. 10 cans for 20 to 24 hr. because freezing was occurring and because, after freezing had occurred, the ice conducted heat very slowly. Sirup of 70° Brix apparently did not freeze, and its cooling curve paralleled that of dry sugar. Heavy sirups cooled more rapidly than light sirups, quite the reverse of rates of heating of cans of sirup in steam. In the latter case heat is carried by convection principally, whereas during cooling it is conducted almost wholly by conduction, a much slower process than convection.

Joslyn and Marsh demonstrated that cooling of cans or paper cups packed in fiberboard or wooden cases was very much slower than of the same small containers standing individually in the freezing room so that the cold air could circulate freely between them. From 10 to 27½ hr. was required for 1-lb. flat cans of fruit pulp to reach the freezing point of the pulp when packed in various types of fiber and wooden cases. Cans in the upper corners cooled most rapidly; those in the lower center position, most slowly; the former cooled about twice as rapidly as the latter. When practicable, it is advisable to cool the small containers before packing them in cases.

They found that the cooling of various products in small containers was about five times as fast in solid carbon dioxide at −110°F. as in air at 2°F. The "freezing period" (period during which the temperature remained constant during and after ice formation) was very much shorter in the solid carbon dioxide than in air at 2°F.

While rates of cooling varied somewhat with the nature of the product, the differences were very much less than those encountered in rates of heating of different canned products, for example, peas and cream-style corn, because, as stated above, cooling in freezing storage occurs principally by conduction. Since most fruits and vegetables consist chiefly of water, their rates of heat conduction will be similar—and similar as well to that of water.

Joslyn and Marsh also followed thawing rates, i.e., temperature rise on removal of the frozen products to room temperature and melting rates after melting temperatures were attained. The "thawing curves" were more or less inverse to the corresponding "cooling curves." There was a characteristic rise to the melting point, a period of several hours at a constant temperature during melting, and then a slow rise to room temperature (Figure 110).

Methods of Freezing. While freezing should be as rapid as possible, in order to forestall undesirable enzymatic changes, the author agrees with Lee et al., Joslyn, Diehl, and others that probably this requirement has been overemphasized by some. While this point has been discussed briefly in an earlier section in this chapter on physical changes occurring during freezing and thawing, the following additional information will be of interest. The term "quick freezing" is a relative one and very difficult to define accurately. It does not signify instantaneous freezing; under practical conditions usually an hour or longer is required to freeze fruits or vegetables in retail packages of the usual sizes and shapes. Woodroof of the Georgia Agricultural Experiment Station has suggested that it might be considered freezing at such a rate that the ice zone travels at 0.3 cm. per min. or faster which is indeed a rapid rate. Pennington has suggested that quick freezing is a rate in which the product being frozen passes through the zone o

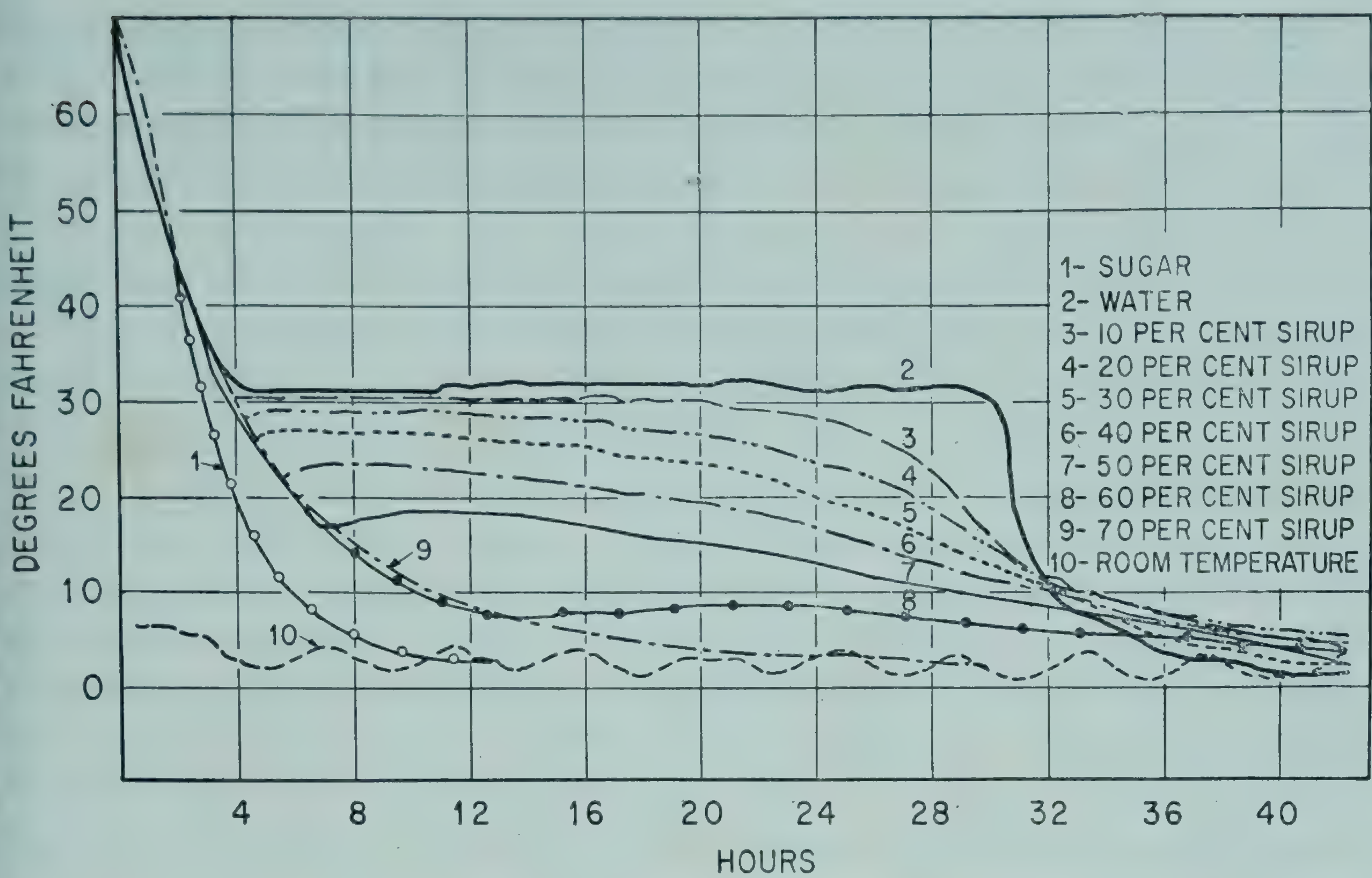


FIG. 110. Rates of cooling and freezing of sirups of various Brix degree in comparison with water. (*After Joslyn and Hohl.*)

solidification (maximum ice-crystal formation) in 30 min. or less. Others have defined it in other manners.

Tressler (1932) has stated that quick freezing minimizes destruction of the intact cells by forming smaller crystals; but Joslyn and Marsh, Diehl and Berry, as well as Lee, Gortner, and Whitcombe have reported that while rapid freezing does give smaller ice crystals in the product, and that on that account one might expect less damage to the tissues, actually there is little or no difference in the physical appearance, texture, flavor, and odor of the quick-frozen and the slow-frozen products after thawing or after thawing and cooking. Tressler also points out that during quick freezing there is less time for enzyme action and growth of microorganisms. Lee, Gortner, and Whitcombe of the New York Agricultural Experiment Station at Geneva (1946) compared the macroscopical appearance, microscopical appearance of cross sections, texture, etc., after thawing and quality of the cooked products, as well, using peas as an example of a starchy vegetable and green beans in the pod as one of low starch content. As noted above, they found no discernible differences after thawing and after cooking of the frozen products. Also they found no differences in losses of vitamins B_1,C, and carotene in the two methods.

In so far as fruits are concerned, Joslyn and Marsh (1932) found that strawberries were of better texture and plumper after thawing if slow-frozen rather than quick-frozen. Slow freezing allows the berries to "cure" to a greater degree in the sirup or sugar during freezing. Similar results have

been reported for other fruits, although Woodroof (1938) favors quick freezing for fruits as essential for maximum retention of texture, flavor, and appearance. In the author's experience and research slow freezing has been observed to be as satisfactory or better than quick freezing for frozen-pack fruits in sirup.

Methods and equipment for the freezing of fruits and vegetables commercially vary considerably. These methods include freezing in still air or in a blast of refrigerated air, freezing of certain products in pans or in metal containers in cold brine or other refrigerated liquid, freezing in rectangular packages between cold plates, and freezing by direct contact with sprays of cold brine or sirup or by immersion in such a liquid. In the early days of the industry barrels or 30-lb. egg tins of berries with sugar were placed in a 0°F. room of the warehouse and allowed to slowly cool and freeze (see section earlier in this chapter on rates of temperature change occurring during this method of freezing from data of Diehl et al.). As a matter of fact it is still used for barreled berries, although they and the sugar are now usually precooled before packing in order to prevent undesirable microbiological activity.

In many plants in Pacific Coast states the prepared and packaged fruits and vegetables are placed on heavy screen trays on small trucks, and these in turn are rolled into a tunnel holding several trucks; then the products are rapidly frozen in a strong blast of recirculated air at −30 to −40°F., i.e., at 30 to 40°F. below 0°F. Or the vegetable, such as peas or whole-kernel corn, may be frozen on trays loose (not packaged) and stored frozen in large bags or cartons for later repacking. Freezing of small packages of fruit or vegetable is rapid, usually within 3 to 4 hr.; freezing of the loose, not-packaged peas, etc., on trays, occurs in much less time than is required for the products in packages.

Another form of air-blast freezer consists of a tunnel through which travels a wire-mesh belt or a series of several such belts placed one above the other. Whole-kernel corn, or peas or diced carrots or other product of small dimensions, is spread automatically in a thin layer on the belt. A strong blast of cold air is blown by fan through the tunnel and recirculated over refrigerating coils. The product may be frozen by a single passage or by passing through the tunnel two or more times on two or more belts, passing from the upper to a lower belt at the end of a trip. Desiccation may be rather severe, and sticking of the product to the belt may occur; passage of the belt over a "hump" will tend to break up the layer of product, or cascading from one belt to a lower one may have this effect; or passage of the cold air downward will have the tendency to cool the product more than it does the belt, and sticking is thereby lessened. The air velocity should be high, in the neighborhood of 2,000 lin. ft. or more per minute. Peas or other product so frozen is free-flowing and used in most plants for

repacking. On that account it may be packaged in large plastic bags inserted in large tote boxes or directly in large cartons or multiwalled bags.

In many plants vegetables and fruits are packed in rectangular cartons or in Sefton fiber cans of rectangular shape and frozen in Birdseye or Amerio plate freezers. The Birdseye freezer was described by Clarence Birdseye in 1932. It consists of a chamber containing a number, usually 6, 8, or 10, of metal shelves through which a refrigerant, either ammonia or Freon, is circulated at very low temperature. The flat packages of product are placed on the shelves, and these in turn are raised by hydraulic lift until moderate pressure is exerted on the top and bottom of each package. The pressure prevents bulging of the package during freezing from expansion of the product on freezing and makes for very rapid transfer of heat (cold) between the plates and the packages. Freezing usually requires less than 2 hr., often 1½ hr. only or even less for certain products. Since expiration of the basic Birdseye patents, 1930 to 1933, other plate-type freezers have come into use, one being the Amerio freezer (Figure 119). Birdseye also invented a continuous-belt-type plate freezer in which the packages are held between parallel metal belts refrigerated by very cold brine. Pressure is exerted on the packages by the two belts, freezing is rapid, and operation is continuous.

Another continuous freezer is that manufactured by the Food Machinery Corporation, although it is not of the plate or belt type. It is being used in several West Coast plants. A second type of FMC freezer resembles that corporation's continuous sterilizer for canned fruits and tomatoes. It consists of a large, round metal shell through which cans of fruit juice or concentrated juice are conveyed by revolving reel through refrigerated brine or alcohol. Freezing is rapid, and small rather than large crystals are formed on freezing. It is used for freezing of 3-to-1 citrus concentrates in California.

In the Finnegan tubular freezer cans of fruit juice or concentrate are placed in tubes of slightly greater diameter than the cans and arranged in a slanting position. Alcohol at about -35°F. is circulated in the tubes counter to the direction of travel of the cans and causes rapid freezing. In another type of Finnegan freezer, cartons or cans of the fruit or vegetable are placed on trays on special cars and frozen in a tunnel consisting of six compartments. In the first one the product is precooled, and in the following four compartments it is frozen in a current of recirculated air, humidified to reduce desiccation. In the sixth compartment the product is tempered. The difference in temperature of the cold air and of the product is less than in other air-blast freezers, a condition that tends to minimize desiccation.

In the Z process, designed by Zarotschenzeff, cold sprays of brine are applied directly to fish or to packaged fish in small cartons to accomplish

rapid freezing. Immersion of fish in very cold brine has also been used for rapid freezing. Fruits, as in the Bartlett and Woolrich method (1942), can be frozen in invert sirup of 50° Brix cooled continuously to the point of incipient ice-crystal formation. On removal from the freezer the excess, adhering sirup can be removed by centrifugal or by draining before packaging. A sirup made up of sucrose, corn sirup, and water may also be used as the freezing medium.

In the York continuous fast freezer used quite extensively in the Pacific Northwest, trays of peas or corn or diced carrots move upward through a tower through which is circulated a strong blast of air at about -30°F. or lower. Filled trays enter at the bottom, travel upward as the product freezes, are dumped automatically at the top of the tower, and the empties are returned to the loading station at the bottom of the tower. The trays are filled by machine, and the product leveled to a depth of about $1\frac{1}{2}$ in. before the tray enters the bottom of the tower.

Other types of freezers exist, but those described briefly in this chapter represent most of those in common use in West Coast states.

Experimentally, fruits and vegetables have been very quickly frozen by contact with solid carbon dioxide, or by contact with thin metal vessels containing solid carbon dioxide. In so far as the author is aware, this refrigerant has not been applied industrially for quick freezing of foods. In Germany during the Second World War foods were frozen by immersion in nitrous oxide at very low temperature, according to Mackinney (1946) and others.

Storage Temperature. Diehl and others recommend that storage temperatures not above 15°F. be used because at higher temperatures certain microorganisms may multiply, whereas at or below 15°F. they decrease in numbers, and because the lower the temperature, the less is chemical and enzyme action. Diehl and Berry report that scalded peas, asparagus, Lima beans, corn, spinach, cauliflower, and string beans retained their color and general quality more satisfactorily at 5°F. than when stored at 15°F. They recommend a storage temperature of about 0°F. (-17.8°C.) for best industrial practice. Caldwell and associates of the Bureau of Plant Industry of the U.S.D.A. and Joslyn, Marsh, and others made similar observations with various vegetables. Some packers store at -5 to -10°F. rather than at 0°F.

Therefore it appears that in order to eliminate danger of growth of certain microorganisms, a storage temperature of not above 0°F. should be used; and in order to reduce enzymic and chemical action to a minimum, the storage temperature should be in the neighborhood of 0 to -10°F.

Use of Sulfur Dioxide in Frozen-pack Fruits. Frozen fruits for use in pies, jams, and other cooked products may be treated with dilute sulfur dioxide solution to prevent their darkening during storage and after

thawing, without impairing their flavor for these purposes. Joslyn and Mrak report that dipping sliced apples in a 0.40 per cent solution of sulfur dioxide for a few minutes (2 to 5) effectively prevented browning during storage and thawing. Pies made from such fruits were so low in sulfur dioxide content that most persons could not taste it. They found sodium bisulfite solution equally effective, more convenient, and not unduly costly. They recommended it in preference to plain sulfur dioxide solution. The addition of 2 per cent of salt to the sulfur dioxide dipping solution increases its effectiveness somewhat.

They recommend the following procedure: Prepare a sodium bisulfite solution equivalent to about 5,000 p.p.m. of sulfur dioxide, or a pure sulfur dioxide solution of about that concentration. To prepare such a solution add about 1¼ lb. of chemically pure sodium bisulfite to each 20 gal. of water. Potassium metabisulfite may be used instead of the bisulfite. Use only paraffined wood, stainless steel, or other material not attacked by the sulfur dioxide.

Peel and core washed apples; discharge the whole peeled fruit into the sulfite or sulfur dioxide solution. Remove, slice, and discharge the sliced fruit into a fresh solution of sulfite or sulfur dioxide containing about 5,000 p.p.m. sulfur dioxide (0.5 per cent). Leave 2 to 5 min. Drain and pack in enameled 1-gal. slipover-top cans, paraffin-paper- or cellophane-lined cartons, or 30-lb. egg cans. Pliofilm bags are also used inside cartons. The cans must be enamel-lined. Store at 0°F. until needed and remove as required. It is recommended that the fruit be thawed at 40 to 50°F.

Apricots are halved, pitted, quartered, and dipped in the solution for about 3 min. or somewhat longer. Peaches of the canning clingstone type are halved and pitted, lye-peeled (Chap. 3), quartered or sliced, and dipped 4 min. or longer in the bisulfite solution. The treated apricots and peaches are packed as described for apples.

Fruits treated as described above may also be packed in wooden boxes lined with waxed paper. In this case, as sulfur dioxide will escape more rapidly than from cans, the sulfur dioxide treatment should be somewhat longer than given above. Cellophane or pliofilm bags inside heavy cartons are preferable to boxes.

Packages of fruits treated with sulfur dioxide or sulfite must be suitably labeled to indicate that they have been so treated, in order to conform with state and Federal food regulations. In 1944 and 1945 considerable quantities of sliced peaches and sectioned apples for bakers' use were packed in this manner, with 1 part of sugar to 6 of fruit.

Ascorbic and Citric Acids. The activity of oxidizing enzymes of fruits is retarded by lowering of the pH value by addition of a permissible acid such as citric. This fact has been utilized by acidifying the rinse water in treating lye-peeled peaches. It has also been used to retard the browning of fruit

purées preserved by freezing and to acidify sirups in which sliced fruits are packed for freezing. Joslyn and Hohl (1948) state that as much as 0.5 per cent citric acid may be added to the sirup without making the fruit too sour in taste. Citric acid probably retards oxidation not only by lowering the pH value but also by forming complexes with the ions of iron and copper in the fruit or sirup, as these two elements are known to be powerful catalysts of enzymic oxidation of naturally occurring tannins and related compounds of fruits.

Ascorbic acid, vitamin C, is now used extensively for the prevention of enzymic oxidation of sliced frozen-pack fruits. It also has a remarkably favorable effect on retention and intensification of the fresh flavor and aroma of fruits packed in sirup. As it is a powerful antioxidant, it rapidly combines with the oxygen present in the sirup and protects the color of the fruit against browning because it is more readily oxidized than are the color compounds and oxidase substrates of the fruits; i.e., the ascorbic acid is oxidized before these compounds are attacked, and as long as an appreciable concentration of ascorbic acid is present they are protected.

Joslyn and Hohl state that if the sirup in which the fruit is packed contains 100 mg. of ascorbic acid per 100 cc., i.e., about 0.1 per cent, the color of the fruit will be adequately protected not only during freezing storage but also during subsequent thawing and standing for several hours after thawing. Another way of expressing the amounts of ascorbic acid used in freezing is as milligrams per pound of fruit. The usual range is 200 to 250 mg. of the acid per pound of fruit. In commercial practice it is usually more convenient to add the ascorbic acid to the sirup as it is being made up in quantity for addition to the fruit on the packaging line.

It may also be added to the dry sugar commonly employed with dry-packed fruits such as strawberries and with fruits such as sliced peaches or halved apricots packed with dry sugar for retail sale (berries) or for use in pie bakeries (apricots, peaches, sour cherries, apples). In a large freezing plant in California in 1955 4 oz. of ascorbic acid was used with each 100 lb. of sugar, and 5 lb. of this dry mixture was added to each 25 lb. of pitted and halved fresh apricots. The fruit and sugar–ascorbic acid mixture were thoroughly mixed in a rotary mixer before packaging in 30-lb. egg tins for bakery use. In another plant 513 lb. of sugar, 11 oz. of ascorbic acid, and 3 lb. of citric acid were mixed with water to give 100 gal. of sirup used in packing sliced peaches for freezing.

Joslyn and Hohl (1948) report that in their experiments a sirup containing 0.5 per cent citric acid and 0.03 per cent ascorbic acid gave good protection to the color of peaches, apricots, and nectarines. The Chas. Pfizer Co., manufacturers of ascorbic acid and citric acid, state that sliced peaches processed with 0.5 per cent of a 4–96 mixture of citric and ascorbic acids (96 per cent citric and 4 per cent ascorbic), corresponding to 90 mg. of

ascorbic acid per pound of fruit, retained excellent color. In other words, the use of citric acid greatly reduces the concentration of ascorbic acid required to protect the color and flavor of the fruit.

DIRECTIONS FOR FRUITS

The following paragraphs have been prepared to serve as working directions for the preparation and freezing of various fruits. They take into account the various principles and practices discussed earlier in this chapter.

Apples. Prepare as for canning. Then immerse in 1 per cent sodium bisulfite solution for about 4 min. Drain. Pack in three-ply cellophane or other plastic bags in 30-lb. cartons and freeze. Or prepare in segments as for canning. Then blanch in live steam long enough to destroy peroxidase enzyme (usually 4 to 7 min.). Cool in a blast of air or by evaporative cooling by the mist air-blast method. Pack as above without sulfite dip. If for household use, pack in 12- to 16-oz. cartons and cover with 30° Brix sirup. Freeze. Sugar may be added at time of packing if desired. Applesauce may be prepared as for canning; cooled; packaged; and frozen.

Apricots. Use only well-ripened fruit. The Blenheim, Tilton, and Royal varieties are satisfactory. Sort, pit, and wash. Airtight containers are preferred in order to prevent oxidation. Cover with a 40° Balling cane- or beet-sugar sirup. Cartons fitted with cellophane or pliofilm bags may also be used. Hohl (1946) and others recommend addition of about 0.10 per cent of ascorbic acid to the sirup.

If the apricots are to be used in bakery products or preserves, an alternative method may be used as follows. Dip the halved or quartered fruit in a 1.0 per cent solution of sodium bisulfite or a 0.5 per cent pure sulfur dioxide solution for about 4 to 5 min.; drain and pack without sirup in a paraffined carton or other suitable container, preferably airtight. The solution used for dipping should contain about 5,000 p.p.m. (about 0.5 per cent) of sulfur dioxide, or its equivalent in sodium bisulfite.

Probably the most satisfactory procedure is to dip in bisulfite or sulfur dioxide as suggested above and then pack in a sirup of 40 to 50° Balling.

An excellent method consists in dipping in dilute sulfur dioxide solution followed by packing with 1 part of dry sugar to 3 or 4 parts of fruit. Another excellent procedure is to slice the apricots and pack them in sirup of 40° Brix containing 0.10 per cent ascorbic acid.

Avocados. This fruit has never been canned successfully; but if sieved or ground it behaves well in freezing storage. Use table-ripe fruit. Peel by hand. Halve the fruit, and remove the pit. Grind coarsely or sieve and add about 1 lb. of sugar to each 5 lb. of fruit. Stir until the sugar is dissolved.

Pack in pliofilm or cellophane bags in cartons, heat-seal, and freeze or pack in cans and freeze. Seal to exclude air. This fruit is excellent for use in ice cream. The sliced or halved ripe fruit becomes mushy on freezing and thawing. Sliced firm fruit is fairly satisfactory in texture for freezing for use in salads. It should be packed in 1 per cent citric acid solution or in diluted lemon juice.

Cherries. Pie or sour cherries are produced chiefly in Michigan, Wisconsin, Pennsylvania, and New York for commercial freezing, whereas the sweet varieties are grown in the West for canning, for Maraschino cherries, and for the fresh market. The principal sour variety grown commercially is the Montmorency, but other varieties are also satisfactory for use in pies and for freezing, among them English Morello and the Early Richmond. At the plant the cherries are often stored for several hours or overnight to firm the flesh and thereby reduce the loss of juice in pitting.

Sour cherries are pitted and usually packed with 1 part of dry sugar to 3 to 5 parts of cherries in barrels or large slipover-top cans, or in heavy cellophane or pliofilm bags in 25- to 35-lb. cartons. They are used by preservers and pie bakers. The pitted cherries provide enough juice to form nearly enough liquid to fill the spaces.

Sweet cherries are, in general, more satisfactory for canning than for freezing storage. However, Bing, Black Tartarian, and other black varieties may be pitted and packed as described for sour cherries.

Figs. Use varieties of rich flavor and tender skin such as the Mission and Kadota. They should be table-ripe, considerably riper than for canning or shipping. Airtight containers are strongly recommended to prevent off flavors induced by oxidation. Pack whole in a 35 to 40° Balling cane- or beet-sugar sirup, or prepare by slicing and then pack with 1 part of sugar to 4 to 6 of sliced fruit. This product is excellent served as a dessert with cream. A short dip in dilute sulfur dioxide solution helps to prevent changes in flavor of sliced figs. Addition of 0.10 to 0.15 per cent of ascorbic acid to the sirup protects flavor.

Grapes. While grapes can be frozen fairly satisfactorily in sirup and, on thawing, rinsing, and draining, are edible and retain the fresh grape flavor, they are rather unsatisfactory in texture, resembling small rubber bags filled with juice. After thawing they rapidly oxidize. The author sees no occasion for freezing them, other than, perhaps, for the use of bakers. The Thompson Seedless variety could be packed in light sirup in 30-lb. cartons for that trade. For the winter fresh-grape trade, grapes, particularly the Almeria (Ohanez) and Emperor varieties, are much more satisfactory packed in cork dust or redwood sawdust in small kegs and held at 32°F. In that condition they keep well until midwinter.

Mangoes. This fruit is very popular in the tropics and is grown commercially in southern Florida and Hawaii. Its importation in the natural

state from Mexico is prohibited because it is a carrier of the dreaded Mediterranean fruit fly.

Experiments conducted by A. Valenzuela of the Philippine Bureau of Science have shown that it behaves well in frozen pack. Freezing destroys the eggs and larvae of the fruit fly; hence freezing should be worthy of consideration as a means of making this popular fruit available to Americans. It is recommended that the ripe fruit be peeled, pitted, sliced, and frozen at once in sirup of 25 to 40° Balling in proper containers.

Nectarines. Procedure is similar to that for peaches and apricots.

Olives. Pickled ripe olives of the Mission variety may be preserved successfully by freezing storage, as experiments at the University of California and those of Diehl have demonstrated. However, they are of superior texture and of approximately as good flavor when canned and sterilized by heat in the usual manner. There is little justification for the freezing storage of this fruit.

Peaches. Peaches vary greatly in suitability for freezing storage, according to variety. Freestones are usually preferable to canning varieties of clingstones. Of the former the J. H. Hale, Elberta, and Rio Oso are quite satisfactory; the Lovell and Solway are less so. The Muir freestone is unsatisfactory because it is mealy and "dry" in texture. Of the canning clingstones the Tuscan and the more highly flavored Midsummer varieties are preferable to the Phillips and similar clings of tough texture and of poor flavor. Canning clings are suitable only for pie bakers and jam making. For the retail pack use only freestones.

Use fruit that is thoroughly table-ripe, fresh, and free of bruises. Cut in half and pit. Peel with steam as described in Chapter 3 for canning. Or lye-peel the whole fruit, wash thoroughly, and then pit. The halves are then sliced, and it is recommended that they be packed immediately in sirup to prevent browning, or that they be treated with sulfur dioxide as described for apricots and packed with 1 part of sugar to 5 of fruit; or that they be packed in 40° Balling sirup containing 0.1 per cent of ascorbic acid. The last-named procedure is preferred (see also section on purées and nectars).

The author sees little reason for freezing canning varieties of clingstone peaches since the canned are so satisfactory and the freestone are so much superior for freezing.

Pears. A fairly satisfactory product from eating-ripe pears can be made and frozen, more or less in the same manner as freestone peaches. However, canned Bartlett pears are very satisfactory, and there is no great need to freeze this fruit.

Persimmons. A very satisfactory product has been made as follows: Soft ripe fruit is rubbed through a stainless-steel screen to give a purée. Iron will cause formation of a black color. One part of sucrose is added to each 5 or 6 parts of purée and dissolved by thorough mixing. Addition of

0.1 per cent of ascorbic acid aids in retention of flavor and color. Pack in hermetically sealed cans or friction-top egg tins. If the latter are used, place on top a layer of Frodex or of sugar. This product is excellent for adding to ice-cream mix, giving an ice cream of golden-yellow color and of pleasing flavor. It is also very satisfactory in milk shakes and is a pleasing dessert when served with whipped cream.

Pineapple. This product has been on the market for several years in the form of rectangular chunks. Experiments at the University of California by Eckart and Cruess (1931) showed that the juice kept well in the frozen condition for several months. The sliced pineapple kept well in sirup of 25 to 40° Brix for about a year, but eventually developed a "stale" taste. The addition of ascorbic acid to the sirup aids greatly in stabilizing the flavor.

Plums and Prunes. In the Pacific Northwest fresh prunes of the Italian variety are frozen commercially. This variety is of deep color and of tart taste and fruity flavor.

Plums are frozen for commercial production of jellies and jams. In experiments in the Food Technology Department of the University of California plums were pitted in an Elliott pitting machine and packed in 30-lb. egg tins and in pliofilm bags in small cartons. The product kept well in freezing storage and was satisfactory for making jam or jelly.

Satsuma, Duarte, Santa Rosa, and other varieties of deep-red color make a good dessert fruit when pitted and packed in a 40° Brix sirup containing 0.10 per cent of ascorbic acid.

Some preserving establishments pit plums and pack them in large containers, such as plastic-lined 50-gal. metal barrels or 30-lb. egg tins, for their own use in making jam or jelly. Also, the frozen fruit is purchased from commercial freezers on the basis of U.S.D.A. grade and careful laboratory examination, particularly in respect to microscopical examination and freedom from leaves or other extraneous material.

Fruit Juices. Experiments at the University of California, some as early as 1917, have demonstrated that most fruit juices retain their flavor and color for at least a year in the frozen condition in hermetically sealed containers such as cans or jars. Citrus juices should be thoroughly deaerated under vacuum before packaging and should be flash pasteurized at 190 to 195°F. to inactivate pectic enzymes that would cause clotting unless destroyed or held in check by other means. The cans should be sealed under vacuum or in an inert gas for maximum retention of flavor and aroma. Apple juice should be deaerated and flash pasteurized at about 190°F. to inactivate oxidasic enzymes and thus check browning. The juices should be packed in enamel-lined cans, paraffined cups, or glass. Storage should be at not above 0°F. Joslyn and Marsh have devised satisfactory procedures for most juices.

Citrus fruit juices curdle during freezing storage and have a very un-

attractive appearance on thawing unless flash pasteurized before freezing to destroy the pectic enzyme concerned. One company homogenizes the juice before freezing in order to produce a finer-grained product and to minimize curdling.

Whether or not juices will be preserved commercially by freezing storage is largely a question of cost to the consumer, since the frozen juices must compete with those pasteurized in cans or bottled and with the frozen concentrates (see the next paragraph). It is doubtful whether the frozen-pack juices can compete in price with the canned and bottled; and their flavor, color, aroma, and general quality in most cases are not sufficiently superior, in the author's estimation, to induce the average consumer to pay a higher price. Nevertheless, one large California packer has been very successful in freezing orange juice commercially in cans for the institutional trade. Apple juice, sweetened boysenberry and youngberry juices, pineapple juice, grapefruit juice, Concord grape juice, and sour-cherry juice are all very satisfactory when preserved by freezing.

Concentrates. As outlined in Chapter 13, orange concentrate for freezing is prepared about as follows by a procedure devised and developed by the Florida Citrus Commission, the U.S.D.A. citrus-products research staff in Florida, and by commercial citrus-juice producers in that state. This product for 3-to-1 dilution, 3 parts of water to 1 of concentrate, has become extremely popular and is now the most important fruit product statistically. In California the Valencia variety only is used, as the other important variety, the Navel, gives a bitter juice. In Florida several varieties are used. The oranges are delivered in bulk to the plant, carefully sorted from a broad belt to remove unfit fruit of all types, stored in slatted bins, and analyzed for soluble-solids content (Brix degree of juice), total acidity of juice, and ascorbic acid content. If a given bin is abnormal in one respect or another, it is blended with fruit from another bin, or the juices from the two or more lots of fruit are blended.

The oranges are soaked and washed very thoroughly in a detergent solution, scrubbed between pairs of rapidly revolving, cylindrical brushes in sprays of water under heavy pressure, rinsed in water containing enough free chlorine to destroy most of the yeasts and other microorganisms not removed from the skins by the preceding washing operations, again sorted, usually size-graded to facilitate operation of the juice extractors, and delivered to the juice-extracting machines. The juice is extracted by Brown, FMC, Citromat, or other automatic juice-recovery unit. It may or may not be centifuged, and is next deaerated. Usually a sieving operation is also included to remove coarse particles of pulp. The deaerated juice is held in a refrigerated stainless-steel tank for a short time, as it accumulates for concentrating. It is customary in some plants to flash pasteurize the juice in order to deactivate pectin-splitting enzymes.

It is concentrated under very high vacuum at not above room temperature in a Mojonnier, Kelly-Howard, or other low-temperature vacuum concentrator to 57 to 60° Brix. Since much of the volatile flavoring compounds is lost during concentration, sufficient fresh juice is added to reduce the Brix degree to 43 and to impart a fresh flavor and aroma.

The blend is frozen to a slushy consistency in a continuous nonagitating, nonaerating freezer, such as a Votator Continuous Slush-Freezing apparatus, and filled by machine into 6-oz. lithographed cans for the retail trade and larger cans for the institutional trade or for the military or other large users. The cans are then quick-frozen in either an immersion-type continuous freezer such as the FMC or Finnegan freezers, previously described, or they are frozen in an air-blast tunnel freezer. They are then cased in fiberboard cartons and stored in a large freezing-storage room, usually at −5 to −10°F. These operations are described in greater detail in Chapter 13, Sirups and Concentrates.

The production and freezing of grapefruit concentrate is done in about the same manner as orange concentrate. Lemonade concentrate is essentially fresh lemon juice standardized in respect to total acidity by blending with concentrated juice and sweetened to about 50° Brix with sucrose. Preparation of the fruit and extraction of the juice are conducted in about the same manner as outlined for oranges. One 6-oz. can of the concentrate makes a quart of lemonade on dilution with water. For details of production, packaging, and freezing, see Chapter 13. It has become very popular for home and institutional use.

Cole (1955) gives the following ranges for several components of frozen lemonade concentrates for 30 brands of the product examined in his laboratory: Brix degree, 48.4 to 55.7; acid ratio 14:1 to 18:1; recoverable oil, 0.028 to 0.066 per cent; and pH value, 2.3 to 2.4. Unsweetened lemon concentrate is also produced, largely for sale to plants in the Middle West and East for reprocessing into frozen lemonade sirup and for other uses. One such concentrate contains 32.5 per cent total acidity expressed as citric acid.

A red concentrate for diluting with three volumes of water before serving is made from Concord grapes and packed in 6-oz. cans for the retail trade. One method of preparing such concentrates is given in Chapter 13, Sirups and Concentrates. The process includes heat extraction to secure a deep red color; depectinization with a pectic enzyme to prevent jellying on concentration; detartration by refrigeration; low-temperature vacuum concentration; recovery of the volatile flavoring esters; blending of the concentrate and essence; packaging and freezing.

Strawberries. Berries will be considered together, taking strawberries as the example. There are two markets for the product, one to the large users, such as preservers, ice-cream makers, and bakers, who desire the berries to

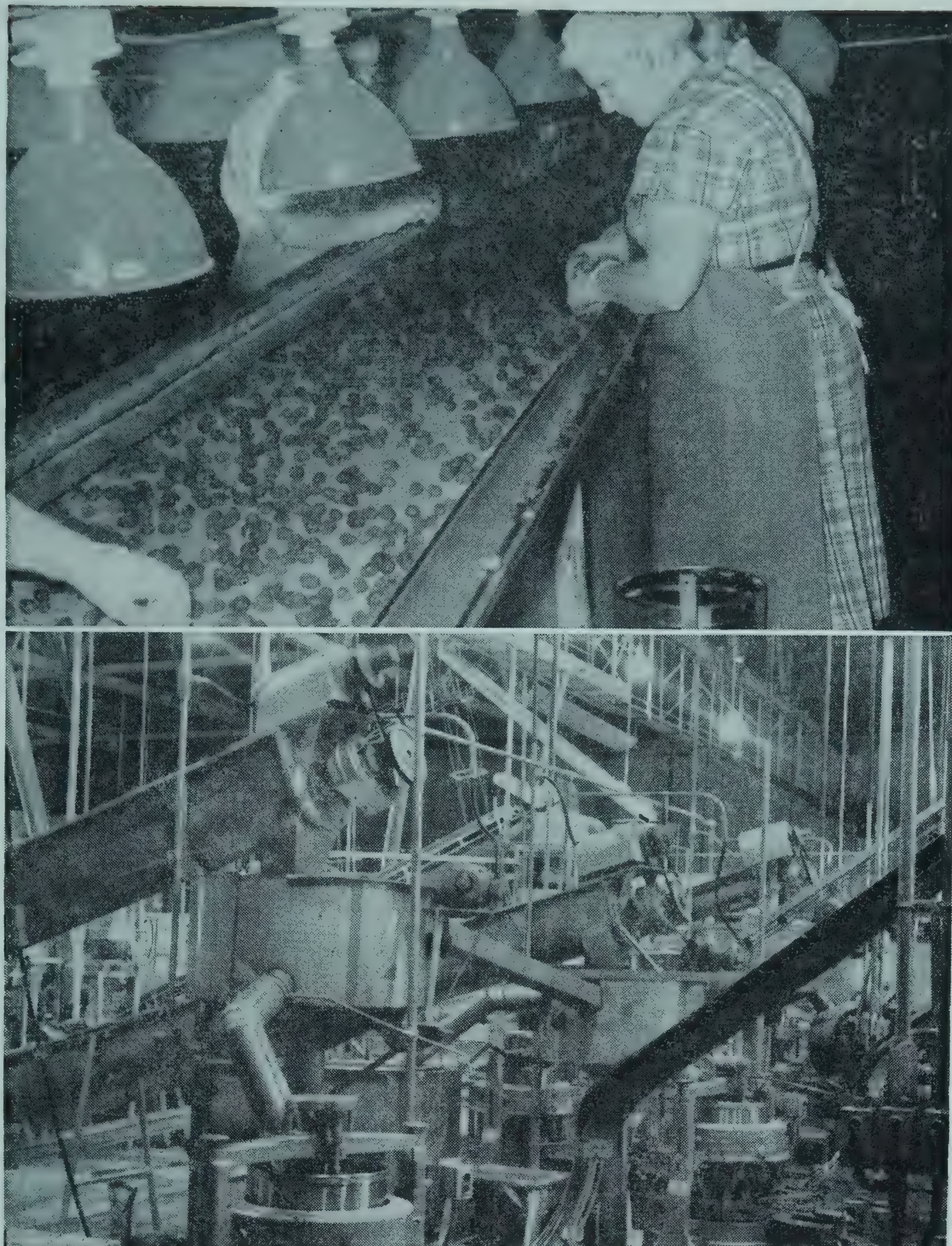


FIG. 111. *Upper:* Sorting strawberries for freezing. *Lower:* Mixers for berries and sugar, hoppers for mixed berries and sugar, and filling machines. (*Driscoll Co., San Martin, Calif.*)

be packed in barrels, 30-lb. cartons, or large tin containers; the second market, at present limited, is to the retail trade, where small containers are desired.

Diehl recommends that firm varieties of deep color, firm texture, and rich flavor be used. They should be picked fully colored and firm-ripe. They are washed and, if to be packed in barrels, should be precooled for 24 hr. in shallow pans or trays at about 32°F. Usually they are picked in the field without hulls, thus eliminating hulling at the plant. The sugar used should

also be precooled. The fruit and sugar are then packed into barrels or enamel-lined 30-lb. egg tins with dry sugar, the berries and sugar being mixed as the container is filled. Care must be taken to see that the sugar does not sift to the bottom of the container and there fail to dissolve. It may be necessary to up-end the barrels to prevent that condition. A head space of 3 to 4 in. is allowed in the barrels for expansion during freezing. The ratio of sugar to fruit will vary with the desires of the purchaser. The usual ratios are 2 plus 1, 3 plus 1, and 4 plus 1, that is, 2 of fruit to 1 of sugar, 3 of fruit to 1 of sugar, and 4 of fruit to 1 of sugar. Some are packed without sugar but are not nearly as satisfactory as the sugar-packed fruit. The total net contents of a 50-gal. barrel of berries and sugar varies from about 400 to 410 lb. for the 4-plus-1 pack to about 450 lb. for the 2-plus-1 pack. Cartons of 25- to 35-lb. size containing three-ply cellophane bags or heavy pliofilm bags are also satisfactory.

In actual practice the berries are usually not precooled before barreling; consequently some growth of yeasts may occur before freezing. Usually the barreling stations are in or near the fields and the barreled berries are transported a considerable distance to the freezing room. Freezing should be at 0°F. or lower and storage at 0°F. or lower.

For the retail trade the berries are usually sliced and then packed in small cartons lined with cellophane, pliofilm, waterproof waxed paper, or parchment, or in paraffined cups, or more often in Sefton fiber cans. For the table use 1 part of sugar to 4 of fruit is a good ratio. Flavor, color, and aroma, however, are better retained in airtight containers and still better in vacuum-sealed airtight cans or jars.

The Pacific Northwest has been an important producer of frozen berries for many years, the Marshall variety of strawberry being favored over others. Disease almost wiped out the growing of strawberries in California a number of years ago; but several disease-resistant varieties have been developed by Thomas of the University of California, and the state is again an important factor in berry freezing. Its output is over 100 million lb. of frozen strawberries per year. The berries are grown under irrigation and bear steadily from midspring until about November 1 in the central coastal counties, where the bulk of the production is located. The principal variety is the Shasta, a large berry of good color, texture, and flavor. The Lassen and Cupertino are also grown in considerable quantities.

Pickings are made several times each week so that the fruit does not become overripe. The berries are picked without hulls, i.e., stems or caps; thus they are ready for sorting and processing on arrival at the plant. Shallow trays (also called flats, crates, or drawers) holding about 14 lb. of berries, are used. The fruit is picked during daylight hours, and most of it is processed and packed at night.

Operations in the freezing establishments vary considerably, but the

following outline is fairly representative. The trays of berries are dumped gently into a small tank of water and conveyed upward to a vibrating, sloping riddle, or screen, on which they are washed under sprays of cold water and delivered to several sorting belts that slope upward. Grades A and B berries are separated, and the culls and green berries are removed. In foggy weather a considerable number of the ripest berries are apt to be moldy and must be discarded.

The berries are then conveyed to a size grader consisting of diverging stainless-steel rods or a stainless-steel sheet with circular openings of two or more different diameters. Usually three sizes are made by the grader. Most of the largest-size berries go to the slicer, and the smallest berries to the bulk line. The slicer consists of a number of circular disk knives rotated by a common shaft. The slices are about $\frac{1}{4}$ in. in thickness. The medium-size berries are also sliced. The sliced berries are next mixed with dry sugar in one of several types of mixing devices. A common arrangement consists of a stainless-steel trough in which is a slowly turning augur. Sliced berries are filled into the trough to a predetermined level at which they make contact with a vertically placed rod, which in turn activates a sugar-measuring or -weighing mechanism which may be operated by electric eye and which adds the required weight or volume of dry sugar. The slowly turning augur mixes the berries and sugar and conveys them to the filling hopper at the end of the mixer. Considerable juice or sirup is formed by osmosis and the mechanical handling of the mix. A batch mixer has also been used which resembles a concrete mixer in general appearance and in operation. Weighed amounts of fruit and sugar are mixed and delivered to the filling machine. A slowly revolving stainless-steel cylinder has also been used for mixing.

From the filling hopper the mixed berries and sugar drop by gravity into an Elgin or FMC or other filling machine that measures the product by volume and places it in the final retail package. The fiber can, the Sefton or other, is a popular and widely used container. It is filled by machine, passed along by conveyer to the lidding and sealing machine where a lid is dropped on each can, and sealed by a machine resembling an ordinary can double seamer. Small cartons carrying an inner, heat-sealable plastic or parchment bag and leakproof cartons without inner bag are also used. The plastic bags are sealed by electrically heated sealing devices as the cartons are carried along by conveyer. The most popular retail-size container is now of 10-oz. capacity; it was formerly 12 oz., but competition has resulted in the smaller package. Cartons are overwrapped in most cases, but the Sefton fiber can is not usually wrapped. Paraffined paperboard cups and key-top cans have also been used as retail containers. A ratio of 1 part of sugar by weight to 4 or 5 of berries gives a pleasing degree of sweetness to the product but the usual ratio is 1 to 4.

The B-grade sliced berries are usually mixed with sugar, as described above, and delivered to a hopper from which they are filled by a hand-operated valve of large diameter into 30-lb. tins for institutional use. The small berries are usually mixed with 1 part of sugar by weight to 4 of berries in a continuous sugar mixer and filled into 30-lb. tins for preservers' use. Also many are packed, especially in the Pacific Northwest, in 50-gal. barrels, the usual procedure being to add sugar intermittently to the berries as the barrel is being filled. The medium-size berries may be included in the barrel pack. Barrels and 30-lb. tins of berries are usually slow-frozen in a large room which may be at $-30°$F. or in the warehouse at 0°F. In order to hasten freezing the air is circulated by fan in some plants. The retail-size packages are quick-frozen in Birdseye or Amerio plate freezers or in an air-blast freezing tunnel, in either method at about -30 to $-40°$F. Storage is at 0° to $-5°$F. in most warehouses.

In one plant in California the cull, the green, and the overripe berries of sound quality and free of mold are puréed in a Rietz disintegrator, infusorial earth and a pectic enzyme are added, and the mixture allowed to stand several hours or overnight to permit the enzyme to hydrolyze most of the pectin, resulting in a product that can be pressed. It is pressed in a combination bag press and filter (Harris press). The juice is concentrated at low temperature under vacuum to a light sirup. The volatile flavor esters are steam-distilled from the pulp, condensed with a small volume of water, and concentrated to a highly flavored essence. About 1 gal. of essence is obtained for each 100 gal. of concentrate. The two are combined later at point of use, which may be for preparation of fountain sirups, jellies, etc. Aref, Sidwell, and Litwiller at Oregon State College (1956) compared various sugars added to strawberries for freezing. There were indications that berries packed with sucrose were superior in flavor to those packed with other sweetening agents. Drained weights were affected more by the ratio of sweetener to fruit than by the kind of sweetener.

Most Oregon and Washington plants and some California plants pack other berries, such as blackberries, currants, raspberries, and boysenberries or loganberries, in addition to strawberries. Much of the pack of these other berries is for the preserving and pie-baking trades.

Raspberries. These are grown extensively in Oregon and Washington for the fresh market, as well as for the preserving and freezing industries. If for the preserving industry the berries are sorted, spray-washed, and packed in slip-cover cans of 30 lb. capacity or of other size, with 1 lb. of dry sugar to 3 lb. of fruit, or in other ratio specified by the buyer. They are also frozen in 50-gal. barrels. For the retail trade they are packed and frozen in about the same manner as previously described for whole strawberries.

Blackberries. Oregon and Washington are important producers of blackberries, the Evergreen being a popular veriety. The berries should be thor-

oughly ripe when picked for freezing; otherwise they may turn red on freezing. After sorting and washing they are often packed whole in 50-gal. barrels or in slip-cover enameled cans of 30 to 50 lb. size, with or without dry sugar. If sugar is used, a ratio of 1 of sugar to 3 of fruit is packed if it is to be used for preserves or jelly, but the ratio will vary according to the specifications of the buyer. At present considerable quantities of blackberries are frozen without the addition of sugar and are used in the production of wine in the Pacific Coast states. For this purpose they may be frozen in the trays in which they are picked or on a continuous-belt air-blast freezer. In this case they are then transferred to barrels or slip-cover cans for freezing storage or shipment to a winery or other purchaser.

Loganberries and Boysenberries. These two varieties are red rather than black in color and resemble each other in general appearance. They are handled and frozen in much the same manner as that outlined for blackberries. In addition to their use in preserves, jellies, and jams, they are used quite extensively by commercial pie bakeries, as are frozen-pack blackberries.

Cranberries. These are produced chiefly in Massachusetts and several other Eastern seaboard states and in the Pacific Northwest. They are cleaned by air-blast and screen-cleaning machines to remove leaves and other light trash, stemmed by machine, washed, packed in slip-cover cans or barrels, and slow-frozen. They keep well without the addition of sugar if desiccation is prevented by use of tight packages. Some are also packed in small cartons for the retail trade.

Frozen Blueberries. The growing of blueberries is outlined briefly in Chapter 8. According to Highlands (1950), about two-thirds of the Maine blueberry crop is canned and about 30 per cent is frozen. Many low-bush blueberries are frozen also in Canada and are imported into the United States, according to *Quick Frozen Foods.* The United States froze about 21 million lb. of blueberries in 1955, and Canadian imports were about 14 per cent of this amount, or about 3 million lb.

According to this report, the procedure with low-bush berries is about as follows: The berries are cleaned in the field by a portable air-blast cleaning machine, similar in principle to a pea clipper cleaner. At the freezing plant they are again air-cleaned to remove berries of low specific gravity; then washed in water over a riffle board that removes stones and other heavy materials; washed in water; strained; surface-dried in a blast of air; critically sorted on a belt; and packed in 22-lb. tin containers or in 30-lb. wax-lined cartons without added sirup or water, for the pie-baking trade.

Bedford and Robertson in Michigan found that blanching of the high-bush varieties Rubel and Jersey for more than 15 sec. gave an inferior product, although Woodroof and Atkinson in Georgia concluded that blanching of blueberries of that region was desirable since it rendered the

skins less tough. Bedford and Robertson recommend packing of blueberries in sirup or with dry sugar for home use. In all cases the berries decreased considerably in weight in freezing storage and thawing, regardless of the preliminary treatment. Mechanically slitting the berries before packing appeared to improve the eating quality.

Blueberries keep well and make good pies even if frozen without sugar or sirup, hence are usually frozen in that condition. They are preferred in the "free-flowing" condition by bakers.

In home freezing the berries may be lightly crushed and sweetened to taste by addition of sugar, or packed whole in sirup or with dry sugar.

Anderson and Esselen in Massachusetts froze high-bush blueberries in 14 different media. If the berries are to be used as dessert fruit, they recommend packing with sugar or heavy sirup. Acceptable pies were made from all the packs except that in 60° sucrose sirup; it was too sweet and the berries were somewhat too firm.

Currants. Some currants are frozen in large containers without added sugar or sirup for use by preservers.

Crushed and Sieved Fruits. Ripe fruits of certain varieties such as guavas, papayas, peaches, apricots, plums, berries of all kinds, mangoes, soft-ripe persimmons, and pears keep well if puréed or sieved and mixed with sufficient sugar to give a palatable dessert together with a small amount of ascorbic acid, about 100 mg. per 100 grams, to prevent browning and loss of flavor by oxidation. In experiments in the author's laboratory at the University of California, a continuous tomato-juice extractor with fairly coarse screen of about 20 mesh was used to make the purées, as it whips less air into the purée than does a tomato pulper of the cyclone type. Aeration should be avoided in so far as possible as the purées oxidize rapidly. For the same reason the ascorbic acid dissolved in water should be added promptly and mixed thoroughly with the purée. Addition of 0.20 to 0.50 per cent citric acid improves the flavor of some purées and tends to retard oxidation. A ratio of 1 of sugar to 4 of purée is satisfactory for tart and subacid fruits; for fruits of low acidity 1 to 6 or 1 to 5 may prove a better ratio. Coarsely ground or crushed fruits of certain varieties may be sweetened and packed in the same manner as the sieved fruits.

Hermetically sealed cans are the most satisfactory containers since they exclude air. If packed in retail-size containers the purées are useful in the home as desserts after partial thawing; or as a base for whips, homemade ice cream and ices, puddings, gelatin desserts, milk shakes, and open-face pies. In the last case they must of course be thickened with cornstarch or egg white.

Nectars. Fruit nectars are pulpy ready-to-serve fruit drinks. The canned nectars have been described fully in the chapter on fruit juices. They may also be preserved by freezing, in which case they possess more of the fresh-

fruit flavor than do the canned nectars. In making nectars the ripe fruit such as freestone peaches, apricots, plums, guavas, and berries of most varieties are prepared as for canning and are then steamed until well cooked, pulped by cyclone pulper, finished by tomato finisher, and blended with approximately an equal volume of sucrose sirup of about the same soluble-solids content as that of the sieved fruit. Some varieties are improved in flavor by the addition of a small amount of citric acid. As the fruit is well cooked before sieving, there is little tendency for oxidative browning. Sefton fiber cans, enamel-lined tin cans, or leakproof cartons such as those lined with pliofilm bags may be used as containers.

Velva Fruits. Sorber and associates of the U.S.D.A. Western Regional Research Laboratory several years ago developed a frozen-fruit dessert to which they gave the name of Velva Fruit. Sugar is added to fruit purée to increase the soluble-solids content to about 37 to 38 per cent, and 0.5 per cent of gelatin dissolved in a little hot water is added as a stabilizer. If the fruit is of low acidity, the addition of a small amount of citric acid will improve the flavor. Ascorbic acid may be required in some cases to prevent browning and loss of flavor. The mixture is frozen in an ice-cream freezer to about 100 per cent overrun in order to secure a frozen product of fine-grained texture. It is packed in ice-cream cartons or other suitable containers and stored at or below 0°F. It is used as a ready-to-serve dessert, a type of fruit water ice. Apricots, berries of all varieties, freestone peaches, persimmons, plums, and canteloupes may be used.

DIRECTIONS FOR VEGETABLES

The following recommendations are based on the best existing knowledge and best industrial practice, which in turn are the outcome of the research of Diehl, Tressler, Joslyn, Marsh, Berry, Woodroof, Sorber, Caldwell, and others (see references at the end of this chapter).

Joslyn and Marsh and others have found that vegetables retain their texture more favorably and lose less weight on thawing and draining if packed in brine; however, thawing of this pack is very slow. Hence housewives prefer the dry-packed products. Large users such as hotels, passenger steamers, and others object to brine pack because of its extra weight and inconvenience of handling and thawing.

Early attempts at freezing storage of fresh vegetables were unsuccessful because enzyme activity in the unblanched products rapidly caused development of a disagreeable haylike flavor and odor. It was reported by Joslyn and Cruess in 1928 and practically simultaneously by Kohman that if the vegetables were thoroughly blanched before freezing their flavor and other desirable characteristics were well retained. Blanching, therefore, is

the most important step in the preparation of vegetables for freezing and is now universal practice.

Asparagus. Green asparagus is probably to be preferred to the white for freezing storage because of its richer flavor and the popular preference for the green color in fresh asparagus. Asparagus is harvested, transported, washed, sorted, cut to length, and otherwise prepared as for canning. In California the stalks are cut in the field by hand, then cut to uniform length by machine at a field house, washed in sprays of cold water, and placed in 50-lb. lug boxes. These are usually held under fine sprays of cold water until loaded on trucks for delivery to the freezer. If they are to be transported a long distance, the stalks may be packed with crushed ice; if held for several hours at the freezing plant, the asparagus may be covered with crushed ice or the opened boxes placed under fine sprays of cold water to minimize deterioration in flavor and toughening of texture. The stalks are carefully sorted for color and graded by hand into several sizes. Also they are usually sorted into A grade, B grade, and culls. Much is cut into short-tip cuts and center cuts. It is customary to blanch asparagus from 3½ to 5 min., depending on size of the stalks, in live steam and to chill thoroughly in cold water.

While there is somewhat less shrinkage of the asparagus packed in a 2 per cent salt brine, there is practically no difference in appearance or texture between the dry-packed and brine-packed products, after cooking the thawed product. It is packed in the usual collapsible cartons, which are waterproofed or contain cellophane or pliofilm bags or liners, in small size for home use and 2 lb. or larger for institutional use. The cartons are then overwrapped with lithographed waxed paper or transparent plastic film, quick-frozen in an air-blast or plate-type freezer such as the Birdseye or Amerio, then packed in fiberboard cartons, and stored at 0 to −10°F.

For success the asparagus must be fresh. Preferably it should be frozen within 5 to 6 hr. after cutting, as it rapidly toughens, becomes stringy, and acquires a bitter taste on standing at room temperature. As with other vegetables, thorough blanching is absolutely essential. All the leading varieties appear to be about equally suitable for freezing storage as they vary but little in flavor and texture.

Unfortunately, asparagus collapses rather badly on freezing and thawing. However, if quick-frozen, after cooking it is not markedly different in appearance from cooked fresh asparagus. It has a fresh-asparagus flavor and color. In most California plants the preparation, packaging, and freezing of asparagus are under continuous U.S.D.A., Agricultural Marketing Administration, inspection and grade certification.

According to *Quick Frozen Foods* the total United States production of frozen asparagus was 12,339,000 lb. in 1944 and 36,194,000 lb. in 1956. About half of the annual pack is produced in the West.

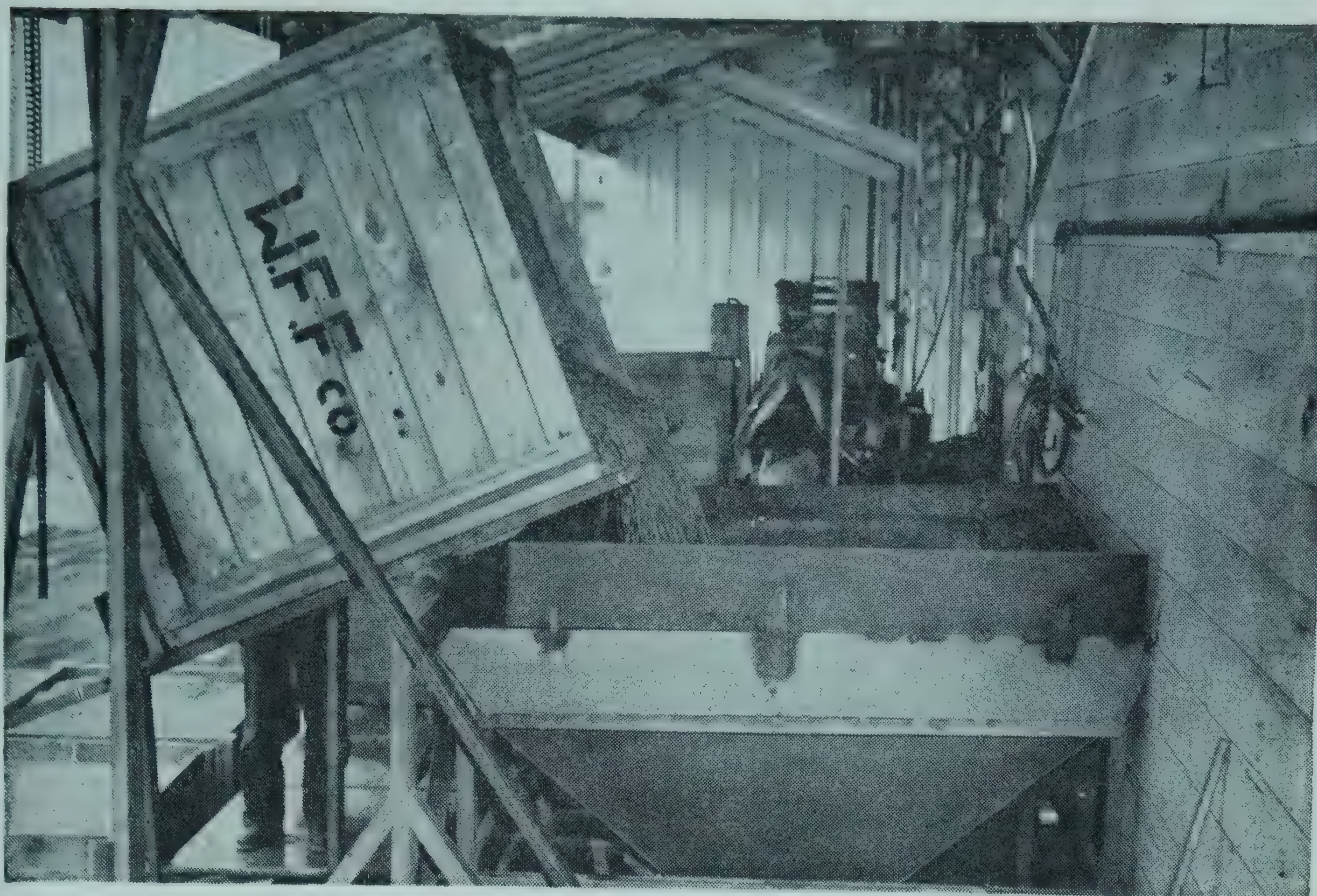


FIG. 112. Dumping tote box of green beans at Western Frozen Foods Co., Inc., Watsonville, Calif. (*Western Canner and Packer.*)

Green Beans (String, or Snap, Beans). Green beans for freezing must be tender and relatively free of woody pod tissue and strings, as woodiness is made more noticeable by freezing storage. In the Pacific Coast states the Blue Lake, a pole bean of exceptionally high quality for freezing, is grown for canning and freezing, almost to the exclusion of other varieties. It is grown on strings attached to a wire strung horizontally about 5 to 6 ft. above the ground between strong redwood or cedar posts. Thus they are grown in long rows that are about 2 ft. apart, with each vine growing to a height of about 5 to 6 ft. The plantings are irrigated regularly, usually by overhead sprinkling. The beans are picked frequently in order to minimize production of overmature, oversize pods. The Blue Lake pods are of deep-green color after blanching, practically free of strings, nearly cylindrical in cross section, and tender in texture and of excellent flavor.

Moon, Caldwell, Lutz, and Culpepper made extensive plantings and comparisons of the freezing quality of many green bean varieties and reported that the Kentucky Wonder, Giant Stringless Green Pod, and Mosaic Resistant Stringless Green Refugee proved very satisfactory for freezing and decidedly superior to the other varieties tested. In California a variety known locally as the Italian Bush Bean is used in one plant for freezing. The pods are rather flat in outline and somewhat variegated in color. They possess good texture and flavor. Wax beans of several varieties are also used for freezing in several green bean-producing regions. In the Middle

West and East bush varieties are more commonly grown than in the West.

The picking of the beans, transportation to the plant, washing, size grading, mechanical snipping, cutting, and blanching are conducted for freezing in about the same manner as described in Chapter 10 for canning. The largest size, No. 7, is usually discarded as being too large and too mature for freezing. Often the smallest two or three sizes are packed whole, uncut. The medium and larger sizes are cut crosswise into short lengths, usually 1 in., or cut lengthwise into French-cut strips. Beans to be cross-cut are blanched after cutting; those for cutting into lengthwise strips, French style, are blanched before cutting, because if blanched after cutting an excessive amount of water solubles would be lost, resulting in a product of "washed-out" flavor. The beans are sorted for quality at least twice, once before blanching and again after blanching. Two quality grades, A and B, are usually made. Blanching is a critical operation because of the tendency of the skins of green beans to sluff (loosen and peel off) if blanched too long or at too high a temperature. On the other hand, the blanching should be severe enough to destroy the peroxidase enzyme in order that a haylike flavor and odor will not develop in storage or in the grocer's sales cabinet. Often the No. 6 size (the largest generally used) is packed for institutional use or is cut into French-style strips. A temperature of 190°F. is used in several Pacific Coast plants for blanching, using a pea blancher for this operation. The usual period of blanching is 2 to 2½ min. at this temperature. The blanched beans are cooled by sprays of water or by fluming, or by both.

Samples are taken frequently for examination in the laboratory for quality, peroxidase test, defects, etc. The peroxidase test may consist in placing a drop of 0.5 per cent guaiacol solution (guaiacol in 50 per cent alcohol) and a drop of dilute H_2O_2 on the cut surface of several bean pods noting whether or not a characteristic brown or orange color develops within 3 to 4 min.; or by placing several cut pieces in a test tube or beaker containing distilled water to which a few drops of guaiacol indicator and dilute H_2O_2 solution have been added. Quantitative methods of peroxidase determination are given by Joslyn (1949).

Packaging, quick freezing, casing, and freezing storage of green beans are conducted in much the same manner as described for asparagus. If the small sizes are packed whole, uncut, packing is a hand operation; the cut beans are usually packed by filling machine or in a semiautomatic hand-pack filler.

The nubbins, the short pieces removed by special machine after the beans have been cross-cut, may be packed in bulk-size packages for use in making soups or for institutional use.

According to *Quick Frozen Foods*, production of green and wax beans in the United States was 23,752,000 lb. in 1944; 65,528,000 lb. in 1950; and

FIG. 113. *Upper:* Side view of spinach harvester and truck. *Lower:* Frontal view of harvester and rows after cutting.

123,253,000 lb. in 1954. In 1956 it was approximately 137,700,000 lb., according to *Western Canner and Packer.*

Lima Beans. Frozen-pack Lima beans have proved very popular and become important commercially. Caldwell, Lutz, and Moon have compared eight common varieties for freezing storage and found King of the Garden and Giant Podded, both pole varieties, and the Dreer Bush variety superior to the others.

The Henderson Bush, a widely grown and popular garden variety, was satisfactory when brine flotation was used to remove overmature beans. In fact, a prime requirement of Lima beans for frozen pack is that they must be of a variety that ripens *uniformly*, or segregation by brine flotation

must be resorted to, as beans that are too mature are unattractive in color and flavor when preserved by freezing. There are hundreds of varieties of Lima beans, and among them there are probably several that are equal or superior to those recommended by Moon and associates. The Henderson Bush (Baby Limas) and the Fordhook are the two varieties usually grown commercially for freezing.

In California Lima beans are grown for freezing near the coast in the southern counties and in the central part of the state near San Francisco Bay. The plants appear to thrive best in this state in regions of cool nights. Lima beans are also grown in other sections of the United States. According to *Quick Frozen Foods*, the production of frozen Lima beans increased from 28,476,000 lb. in 1945 to 138,594,000 lb. in 1953. The 1956 production was approximately 143,600,000 lb. Of the 1953 production 64,390,000 lb. was of the Baby variety and 74,204,000 lb. was of the Fordhook variety.

The vines are grown under irrigation in California and are harvested in August and September. As they approach the desired stage of maturity they are inspected frequently by field men, since the beans are at optimum maturity for freezing for only a few days. The vines are cut by tractor-drawn cutter bar slightly below the surface of the soil and windrowed. The cut vines are picked up by machine and loaded into dump trucks and delivered to the vining station. Viners similar in design and size to those used for vining peas are employed. In California a single vining operation is used; in the Middle West and East two viners in series are sometimes used, the first operating at slow speed to shell the more mature pods, and the second at high speed to shell the smaller pods, which are more difficult to open. In this manner less damage is done to the larger beans. In California the waste vines are either sold fresh to dairies for direct feeding, or more frequently they are filled directly into a deep pit silo (deep excavation) beside the viners. The vines are "tramped" compactly in the silo by a track-laying tractor. Later in the fall and winter they are fed to livestock (Figure 105).

In the field the shelled beans are caught in lug boxes and taken a short distance to a clipper cleaner where leaves and other trash are removed by air blast and screening. They are placed in 50-lb. lug boxes and filled about half full only in order to reduce the tendency of the beans to heat and "sweat." One plant places the beans as shelled into a large tank truck or metal tote bins, in which they are mixed with crushed ice as the tank or bin is filled. In either method the shelled beans are taken as promptly as possible to the freezing plant, located usually within 5 to 20 miles of the fields. At least one operator washes the beans at the vining station after vining and clipper cleaning.

While methods of handling and preparation vary somewhat in the different plants, the following outline is fairly representative. The beans are

passed over a "scalper screen" to remove trash, such as pieces of vine, stems, leaves, large stones, etc. This is followed by passage through a clipper cleaner for further separation of trash and beans. In some plants they are next passed through a riffle cleaner in which are flowing water and fixed baffles. Rocks and other heavy foreign objects sink and are caught in the riffles. In at least one plant the beans are passed through a very powerful suction blast of air after the clipper cleaner; the air suction removes loose skins and light, immature beans and other light material.

The cleaned beans are conveyed into a soaker-washer in which dust and soil are loosened and removed. Some of the sluffed skins are also removed in the soaker-washer.

In the next operation the beans are passed through a brine separator in which the overripe beans sink in a brine of 80 to 85° salometer and those of proper maturity float. They are then spray-washed to remove adhering brine and are sorted on a slowly moving belt to remove overripe beans that passed the brine separator and to pick out sluffed skins or any other undesirable material. Next flotation in a light brine removes remaining sluffed skins and other undesirable material of low specific gravity. A second separation in strong brine may be used to remove remaining overripe beans.

The beans are blanched in a pea blancher in water at about 210°F. or in a steam blancher, in either case long enough to inactivate peroxidase. This requires 3½ to 5 min. blanching, depending upon the maturity of the beans. The blanched beans are cooled under sprays of water and flumed to an automatic filling machine, although a final sorting may be given before they reach the filler. If cartons are used, these are usually of the type that is opened by machine and automatically filled. Sefton-type cans (of cardboard and metal ends) may be used. Cartons after filling are usually overwrapped.

Freezing is done either in a blast of air at -30 to -40°F. or in a plate freezer of the Birdseye or Amerio type. Some of the beans are frozen on trays and packed in large cans or bags or other bulk containers for repacking later or for sale to large users of Lima beans. The overripe beans may be soaked in water several hours, washed, blanched, and packed in bulk for sale to soup canners or other large users. With the Baby (Henderson Bush) variety the proportion of overripe beans is often appreciable.

The Fordhook variety is popular for freezing. The beans are much larger than those of the Henderson Bush, but also are more easily bruised in vining and other operations. Therefore more care must be taken in handling the shelled beans, but in other respects they are treated like the Henderson Bush.

Broccoli. This vegetable is a member of the cabbage family and possesses the flavor of that group. It produces several blossom stalks on each plant, and after trimming and cutting to proper length for packaging, the stalks resemble asparagus spears. The plants thrive best in a cool climate, as

along the California coast. If grown in that region during the winter and early spring, irrigation is usually not necessary; if grown in late spring and early summer or in early fall, irrigation may be necessary in the West. It is grown quite extensively in the Willamette Valley of Oregon, where the rainfall and temperature are quite favorable. It was being frozen when several plants in that area were visited in September, 1955; and in plants in the coastal region south of San Francisco, in December as well as in March and April. The broccoli plants are very subject to infestation by aphids, and at one time these insects became so numerous that much of the broccoli was not fit for freezing. However, in recent years excellent control of this pest has been achieved by dusting the vines with one of the newer contact insecticides, with most of the stalks arriving at the plant practically free of aphids. Each stalk has several leaves and a blossom head. The broccoli is cut by hand in the fields, while the blossom head is in the early-bud stage.

The broccoli must be handled quickly after cutting since in warm weather the buds are apt to open and thus make the stalks unsuitable for freezing. It is quite resistant to handling; consequently it is sometimes placed by the pickers in tote boxes holding several hundred pounds. These are handled by lift truck. The usual field container, however, is a crate which when filled can be handled readily by one man.

In one large California plant the sequence of operations was about as follows. The tote box of broccoli was dumped on a concrete floor, then elevated to a slowly moving conveyer from which women workers positioned the stalks on a second conveyer, which carried the broccoli to a rapidly revolving, sharp disk (circular) knife which cut the stalks to about 5 in. in length. The waste butts were conveyed to a large overhead bin outside the plant, to be taken by dairymen or for disposal in other manner. The cut stalks were trimmed by hand, surplus leaves removed, and large stalks were split lengthwise so that they were of more or less the same size as the medium-size whole stalks. They were then washed by conveyer through a shallow tank of water containing a detergent. During this "trip" the broccoli was violently agitated with powerful jets of the washwater operated by a circulating pump attached to the washing tank. The detergent is expected to loosen any aphids, dust, or mud that may be on the product. Next a vigorous washing under sprays of water followed. A second tank-type washing in water was given, and finally a spray wash. The stalks were then blanched in steam for about 3 min., cooled by water sprays, sorted, and inspected very carefully on a belt. They were packed by hand into leakproof cartons, the cartons closed, overwrapped in lithographed waxed paper, trayed, and frozen in an air-blast freezing tunnel at −30 to −40°F. The cartons were then cased and placed in freezing storage at −5 to −10°F. In California plants broccoli is blanched in steam long enough to destroy peroxidase.

FIG. 114. Removing butts of sprouts with Magnuson Hydrouts, in the John Inglis plant, Santa Cruz, Calif. (*Western Canner and Packer.*)

In the Northwest plant the stalks were delivered in crates; sorted; cut by hand to about 5 in. in length; trimmed, and the larger heads or stalks split to give pieces of desired diameter; the stalks blanched a short time in hot water to loosen any adhering soil and occasional aphids (if any); tank-washed with a detergent solution, as described above; spray-washed, sorted, blanched, chilled in sprays of water; sorted, packed by hand in Marapak-type cartons holding 10 oz. each; and the cartons closed, over-wrapped, and quick-frozen in a plate-type freezer (Birdseye). Blanching was not very "heavy"; sufficient to destroy catalase but not peroxidase.

Production of frozen-pack broccoli for selected years has been, according

to *Quick Frozen Foods*, 6,839,000 lb. in 1944; 25,788,000 lb. in 1946; 41,027,000 lb. in 1950; 89,042,000 lb. in 1953; and 118,300,000 lb. in 1956.

Brussels Sprouts. A moderate quantity of Brussels sprouts is frozen, chiefly in the West, the United States pack in recent years ranging from 22,454,197 lb. in 1952 to 44,000,000 lb. in 1956, according to *Western Canner and Packer*.

A variety that produces very "solid" heads of green color is grown for freezing. These are cut from the stalks in the field by hand and delivered in tote boxes to the freezer. In California plants the heads are trimmed one by one by Magnuson Hydrout fed by hand. They are then inspected, sorted, trimmed by hand if that is needed, washed, blanched in steam or in water at or near the boiling point for a sufficient time to inactivate peroxidase enzyme, spray-cooled, flumed to the filling stations, dewatered by screen, filled into small cartons by hand or by semiautomatic hand-pack filler; weights checked and adjusted; cartons closed, overwrapped, trayed, and frozen in a plate freezer such as the Birdseye or Amerio or in an air-blast freezer, cased, and stored. As is the case with other vegetables of the cabbage family, sprouts are grown in California in counties bordering the coast or San Francisco Bay.

Cauliflower. While cauliflower is available in the fresh form in most markets throughout the year, it is scarce and high in price during the winter months in the Middle West and East; while the frozen product is in convenient form and not unduly costly. On that account frozen-pack cauliflower is a moderately important product, the output in recent years ranging from about 12 million to 25 million lb. annually for the entire United States, according to *Quick Frozen Foods*. It is grown extensively in the coastal counties of central California and in the Pacific Northwest for fresh shipment and for freezing. Varieties that produce large white heads are grown. Often a rubber band is placed around each head in the field in such a manner that the leaves cover the head completely during growing, resulting in curds of white color.

The heads are cut by hand in the field, then placed in wooden tote boxes or portable metal bins holding about 1,000 lb. each, in which they are delivered by truck to the freezing plant. In a large California plant the operations during the 1955 season were about as follows: The head of cauliflower was held against a Magnuson Hydrout, similar to that previously described for coring tomatoes (Chap. 10; also Figure 114). The Hydrout's water-driven, rapidly revolving, guarded, special knife neatly cores the cauliflower head and loosens the curds (individual flower stalks). The leaves and cores are discarded. A coarse screen separates the curds from small pieces of core and leaves. Women separate and trim the curds at a slowly moving belt conveyer. A revolving screen removes small pieces of waste and delivers the curds to a blancher where they are blanched for

5 to 6 min. in water at, or near, the boiling point. They are cooled by fluming to the filling stations. Rectangular retail-size cartons are filled at a semiautomatic hand-pack filler, beyond which women weigh each carton and adjust the filled weight as needed. The cartons are closed, overwrapped, and frozen on trays in an air-blast freezer or in a plate freezer. Blanching is sufficient to destroy peroxidase. In another California plant the procedure is similar to the foregoing except that steam blanching is used. Kaloyereas (1947) found that blanching of cauliflower and spinach was improved by addition of about 5 per cent of sodium sulfite to the blanching water.

In an Oregon plant in 1955, the heads were quartered vertically by a semiautomatic device. The quartered heads were then cut to length, trimmed, and split to give pieces of uniform size. These were washed and blanched sufficiently to kill catalase enzyme but not peroxidase. The packed cartons were frozen in a plate freezer.

Cauliflower on prolonged freezing storage frequently develops a pink or reddish-brown color, whether or not it has been heavily blanched. Acidification of the blanching water has a retarding effect on such discoloration, but the mechanism of the discoloring reaction is not at present clearly understood.

Carrots. Diced carrots are frozen in retail-size packages with or without peas and also in large containers for use by soup canners, producers of baby foods, and for the institutional trade. The pack, according to *Quick Frozen Foods*, was 22,269,107 lb. in 1952 and 29,331,684 lb. in 1953. It was 51,000,000 lb. in 1956 according to *Western Canner and Packer*. Of the 1954 output 17,792,575 lb. was produced in the West. California, Oregon, and Washington are important carrot-producing states.

The Red Cored Chantennay variety is often grown for freezing because of its deep color, good flavor, and desirable texture. The carrots are dug by machine or pulled by hand in the field, tops removed, and the carrots bagged or placed in tote boxes holding several hundred pounds. At the freezing plant they are run through a large revolving reel that removes much of the adhering soil, clods, stones, and other debris. They are soaked to loosen soil and washed under heavy sprays of water. Workmen then place the carrots on a chain conveyer in such a position that two circular rapidly revolving knives cut off about an inch of the root and a like amount of the top to remove the green portion found on most specimens. They are peeled in an FMC steam-under-pressure peeler or in hot lye solution; in either method they are then washed in a rotary spray washer to remove the disintegrated peels. They are inspected and trimmed and then diced in an Urschel vegetable dicer or other machine; and blanched in steam or in boiling water for a sufficient time to inactivate peroxidase. Steam is preferable to water for blanching since it removes less of the water-solubles.

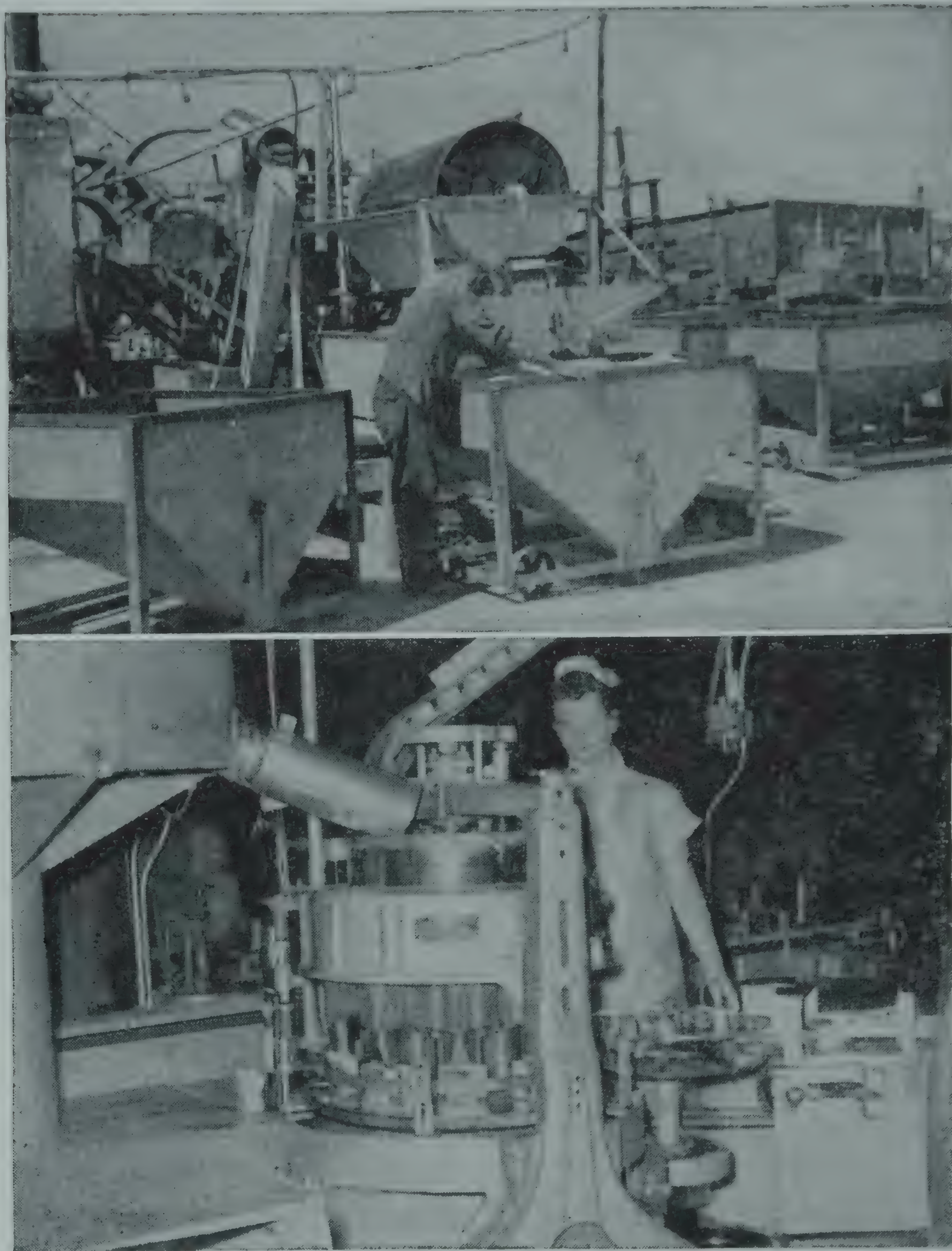


FIG. 115. *Upper:* Metal tote boxes for hulled Lima beans. Rotary washer in background. *Lower:* Filling blanched Lima beans into cartons by automatic filling machine.

The blanched carrots are spray- or flume-cooled and packaged in small cartons for the retail trade or are frozen loose on trays or in a continuous belt freezer and packaged in moistureproof bags, large slip-top cans, or other large containers for repacking later with peas or for sale to canners and others for reprocessing. If thoroughly blanched, carrots retain their flavor and fresh odor very well in freezing storage; but if underblanched they are apt to develop a haylike flavor and odor. The cubes are usually about ⅜ by ⅜ or ⅜ by ¼ in. in size.

Corn. Sweet corn is packed either as corn on the cob or as cut corn.

For use in frozen pack the varieties used should possess an extended period of succulence, tender texture, pleasing flavor, and if for packing as corn on the cob, a small well-filled ear with even rows of kernels. A yellow or golden color is at present preferred to the white. Consequently the Golden Bantam and some of its hybrid crosses have been most popular for freezing storage. Caldwell, Lutz, Culpepper, and Moon compared 35 varieties of corn grown for two seasons on the experimental plots of the U.S.D.A. near Washington, D.C. They placed the following yellow varieties in the first group in respect to desirability for frozen pack: Bantam Evergreen (Golden Evergreen), Bantam Evergreen hybrid (Asgrow 24 × Purdue 39), Golden Bantam, Golden Bantam Improved 10- to 14-rowed, Top Cross Bantam, Top Cross Whipple's Yellow; and the following four white varieties: Money Maker, Narrow Grain Evergreen, Stowell's Evergreen, and Stowell's Evergreen hybrid (Asgrow 14 × Asgrow 5). Of these, all except Stowell's Evergreen, Stowell's Evergreen hybrid, and the Golden Bantam Improved 10- to 14-rowed were satisfactory for either corn on the cob or cut corn; these three varieties possess too large ears for packing as corn on the cob. Country Gentleman, a well-known and very popular variety in the fresh market, and 12 other varieties were placed in the second group and rated nearly equal to those in the first group. In the Salem area of Oregon the Northrup King 18 Row, a yellow variety, is grown extensively. Hence there are many varieties suitable for frozen pack.

Diehl as well as Caldwell and associates emphasize that corn for frozen pack must be picked while tender, well before the "dough stage" and while still definitely in the milk stage. In the Washington, D.C., district this is at not more than 20 days after appearance of the silk.

While much of the annual pack of frozen corn is produced in the Middle West and East, slightly more than half of the United States total output has been produced in the West in recent years, according to *Quick Frozen Foods*. For example, the total United States packs of frozen cut corn were 62,683,636 lb. in 1952, 104,809,364 lb. in 1953, and 78,211,581 lb. in 1954. The corresponding packs in the West for those years were 34,834,028 lb., 65,268,505 lb., and 42,239,111 lb., respectively. The total United States packs of frozen corn on the cob for 1952, 1953, and 1954 were 14,196,021 lb., 17,217,147 lb., and 16,787,099 lb., respectively, as reported in *Quick Frozen Foods*. The West also produced somewhat more than half of this product. According to *Western Canner and Packer* the 1956 pack of cut corn was 118,200,000 lb. and of corn on the cob 20,400,000 lb. California produces almost no frozen-pack corn, but Oregon and Washington pack considerable quantities.

While procedures for preparation and freezing of corn were not identical in all plants visited in Oregon in September, 1955, the following outline is

more or less representative. In general, preparation operations of corn for freezing are very similar to those for canning, as described in Chapter 10.

The ears are picked by machine drawn by tractor. In the Salem area the FMC corn picker was in use in a large field near Salem. A truck driven parallel to the picker received the ears and delivered them to the freezing plant. The ears were husked and butts cut off as described for canning in Chapter 10. The husked ears were inspected and sorted on a slowly moving rubber belt. They then passed through a desilking reel and washer. They were again inspected and sorted; the best ears were placed on a belt for delivery to the corn-on-the-cob department, the remainder to the cut-corn lines. These latter ears were given a short blanch in live steam, usually about 1 min., in order to "set" the "milk" (coagulate the juice), so that the kernels would not leak on cutting. The kernels were then cut from the cobs, as described in Chapter 10. The cut corn was then desilked in a cut-corn desilker and washed. It was inspected on a belt, and any defective kernels, silks, pieces of cob, etc., removed. It was then passed through a flotation separator in which the kernels sank in water and light trash floated and was removed automatically. The kernels were then dewatered by screen, given a final inspection, and then blanched for 2 to 2¼ min. in live steam, i.e., a blanch sufficient to inactivate peroxidase enzyme. The blanched corn was cooled by sprays of cold water (in one plant by water refrigerated to near the freezing point). The corn was then frozen loose on screen trays in an air-blast freezer or in a continuous air-blast tunnel on a traveling screen conveyer. It was then stored at −5°F. or lower in bags or in large tote boxes containing plastic bags, for packaging later in retail packages as cut corn or in combination with frozen Lima beans or cut green beans. Some of the cut corn was packaged in retail-size cartons directly after blanching and spray cooling; the packages were overwrapped, frozen, cased, and stored.

The husked ears for freezing on the cob were inspected and then cut by machine to proper length to fit the retail carton. The ears were then given a long blanch in live steam, usually 7 to 8 min. They were then thoroughly cooled by sprays. Considerable evaporative cooling occurred during spray cooling. The cooled ears were then packed two per carton, or were frozen on trays and stored in the freezing warehouse for packaging later. If corn on the cob is not very thoroughly blanched, enzymes in the cob will cause the development of off odors and flavors during storage. A short blanching period of 3 to 4 min. recommended at one time by several investigators is now considered inadequate.

Peas. At present peas are the most important of the frozen-pack vegetables. For this purpose they should be tender, sweet, of tender skin, and of deep-green color. Moon, Caldwell, and Lutz compared 18 varieties grown near Washington, D.C., during two seasons. They found the Thomas

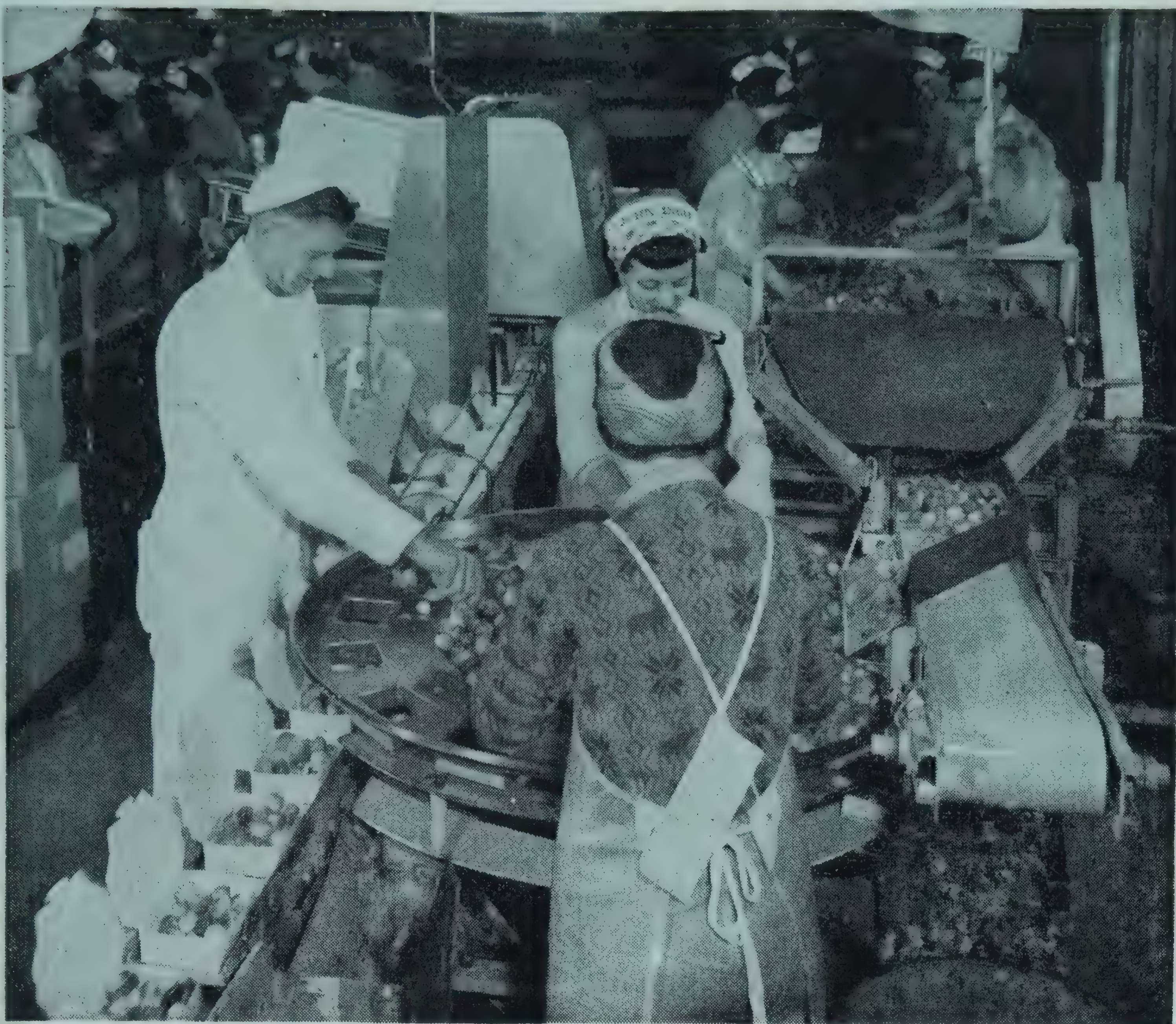


FIG. 116. Packing sprouts for freezing, in the John Inglis plant, Santa Cruz, Calif. Same equipment is used for other products. (*Western Canner and Packer.*)

Laxton and Asgrow 40 superior to the other varieties tested by them. Nearly as satisfactory were the Dark Podded Telephone, Onward, Alderman, and Laxton Superb varieties. Several varieties were found very unsuitable for freezing. In Oregon and Washington the Dark Seeded Perfection is grown extensively for freezing. Doughty, a commercial freezer of peas, states[1] that at present the Dark Seeded Perfection, Perfected Freezer, Perfection Freezer, Early Freezer, and Wyola are important varieties grown for freezing in California. Diehl states that if Laxton's Progress, Stratagem, and Alderman are planted, fairly continuous production through the season can be secured. It is customary to space the planting times of a single variety so that peas will be available over a period of several weeks.

The principal producing areas for peas for freezing in the United States are in the Pacific Northwest in Oregon and Washington, in the Middle West in Minnesota and Wisconsin, and in the East in New York, New Jersey, and Maine, although they may be grown successfully in other areas,

[1] Personal communication.

as in Colorado, Idaho, and Michigan. They are now grown in California quite extensively for freezing. According to *Western Canner and Packer*, the total United States pack in 1956 was 359,700,000 lb., that of the Pacific Northwest, 214,710,000 lb. and California, 31,500,000 lb.

Varieties that ripen more or less uniformly and at one time are planted, and the field of peas is harvested by machinery at a stage of maturity that is considered optimum for the crop as a whole. Some of the peas will be overmature and starchy, and some of the pods will not be filled, or the peas will be too small and immature. The attempt is made to strike a happy medium. If, however, a few days of unseasonable hot weather should occur, much of the crop will become too ripe for best quality.

At any rate, when the field department of the freezing plant decides that a given field of peas is ready to harvest, the vines are cut by swather, windrowed, and elevated by special traveling loader into a truck. Or, as in California at present, a special harvester is sometimes used, similar in principle to the grain header used in the West some 30 to 40 years ago for harvesting wheat and barley. It consists of a low cutter bar, special guards for the knife, a revolving reel above the cutter bar, a draper, and an elevator. The cutter bar is in front of the machine, which is powered by a tractor placed behind the machine, or the machine is drawn by a tractor. The knife cuts the vines, the reel carries or forces them on to the draper, and the elevating draper carries them into the bed of the truck that is being driven beside the harvester (see also Chapter 10, on harvesting peas for canning).

Speed from the mower or harvester to the viner is extremely important, far more so than in canning, because delay results in loss of sugar, loss of flavor, and starchiness. The viner is usually near at hand and is of the same type previously described for the vining of peas for canning. The shelled peas are collected in boxes and should be taken at once to the factory. Delay allows the viner juice (from pods and vines) to dry on the peas, giving them an off flavor. If the trip is a long one, requiring more than a few minutes, it will be advisable to chill the peas by placing a generous amount of cracked ice on each box of peas. If the delay is too long, bacterial spoilage en route may occur.

Several plants in the Pacific Northwest haul the freshly cut vines to viners located adjacent to the freezing plants. The shelled peas are flumed immediately to the preparation department, after being passed over a "scalper" screen that removes coarse trash, and through a clipper cleaner. Also, the peas that are vined in the field are given these two operations, viz., scalper screening and clipper cleaning.

In freezing plants in Eastern Oregon and Washington in the Walla Walla and Milton-Freewater area, the flow sheet for preparing and freezing was about as follows in July, 1955: A 25-lb. sample of each delivery of shelled

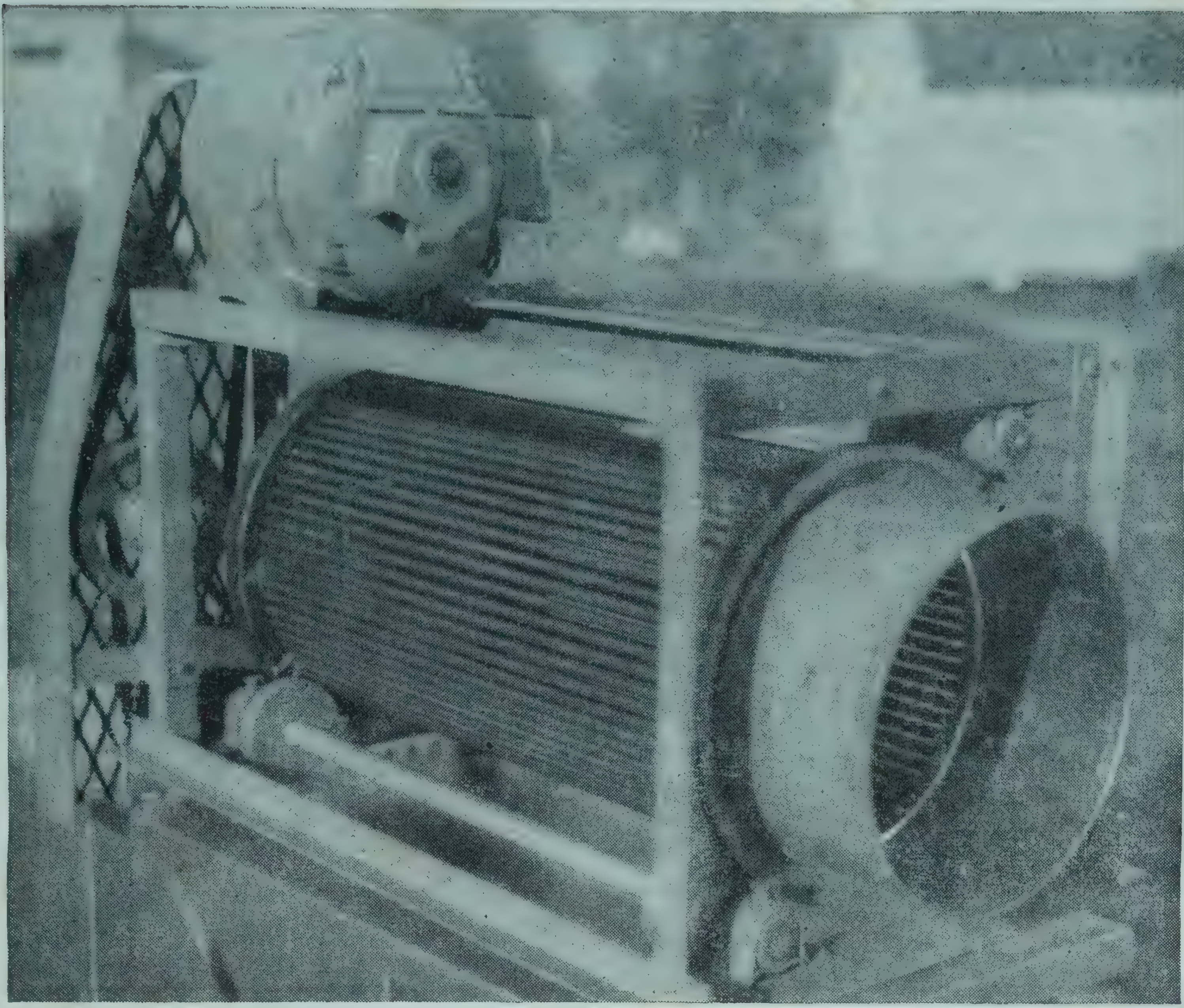


FIG. 117. Hydraulic separating screen, or dewatering reel. (*Berlin Chapman Co., Berlin, Wis.*)

peas was taken and passed through a laboratory-size clipper cleaner to determine the percentages of peas and trash, and part of the sample was tested in a tenderometer to determine the maturity and general quality of the peas. For freezing it was considered that the tenderometer test should be below 90 for A-grade peas. A 10-lb. sample was size-graded in a laboratory-size, revolving, perforated-cylinder-type grader, a test that is always made upon peas to be canned but sometimes omitted if the peas are to be frozen, since, if the peas are fairly uniform in size, they are not graded for size in the plant. The grower is paid on the basis of these laboratory tests (see also Chapter 10).

After passage over a scalper screen and through a clipper cleaner the peas are washed thoroughly and may or may not then be graded for size; usually not. The next operation is a very important one, that of separation of nightshade berries, thistle buds, vine fragments, skins from broken peas, and defective peas of low specific gravity from the whole, sound peas, by means of a Key-type flotation separator. This machine has been described in the section on pea canning in Chapter 10. On agitation of the peas and

accompanying material in a solution containing a special soap and an emulsion of a light, colorless, tasteless mineral oil in water, the nightshade berries, thistle buds, and other trash rise to the surface and the peas sink. The peas are continuously conveyed or pumped to a spray washer in which adhering soapy solution from the separator is washed away. The thistle buds, nightshade berries, and other waste are discarded.

The peas are then blanched in water in a standard blancher such as that described in Chapter 10; in some plants at 210°F. for about 2 min., in some long enough to inactivate the peroxidase enzyme; in one large plant the length of blanch was 3½ min. In at least one plant blanching is less severe, sufficient only to inactivate catalase but not peroxidase. After blanching the peas are cooled by sprays of water and by fluming or by fluming only. They are next separated into two quality grades, that is two degrees of maturity, by passage through a brine quality separator. Usually the brine is 38° salometer and is closely controlled at that degree by a Taylor or other control instrument. When the brine decreases in salometer degree through dilution by the water adhering to the peas, the instrument opens a valve that admits saturated brine in the proper amount, or if the salometer degree rises above 38° for any reason, the instrument adds water. The peas are then washed in sprays of water to remove adhering brine; flumed; dewatered by screen; critically inspected and sorted on a belt; delivered to the automatic filling machine similar to that described in Chapter 10 for filling of peas into cans; filled into cartons; the filled cartons sealed and overwrapped and then quick-frozen in a plate-type freezer such as the Birdseye or Amerio or in an air-blast freezer at 30 to 40°F. below 0 (−30 to −40°F.). They are stored in fiberboard cases at or below −5°F.

Many of the peas are frozen in bulk on trays in an air-blast tunnel freezer, or York tower-type air-blast freezing unit, or on a belt in an air-blast tunnel-type freezer; and packed in moistureproof bags or in other large containers. These bulk-frozen peas are stored and used later for mixing with diced carrots or for repacking in other manner or for sale to soup manufacturers, baby-food canners, or other processors. They are free-flowing.

A frequently made quality test for peas for freezing or canning is the brine flotation test. In one plant this was conducted as follows: Fifty peas were skinned with the fingers, and the cotyledons separated. These were then floated into a 13° salometer brine in a beaker, and the percentages of floaters and sinkers determined within a certain period. It was considered that A-grade peas should float, or at most that only a small per cent should sink.

In some plants the two quality grades separated in the plant in the brine separator were packed as A and B grades; in at least one plant the peas

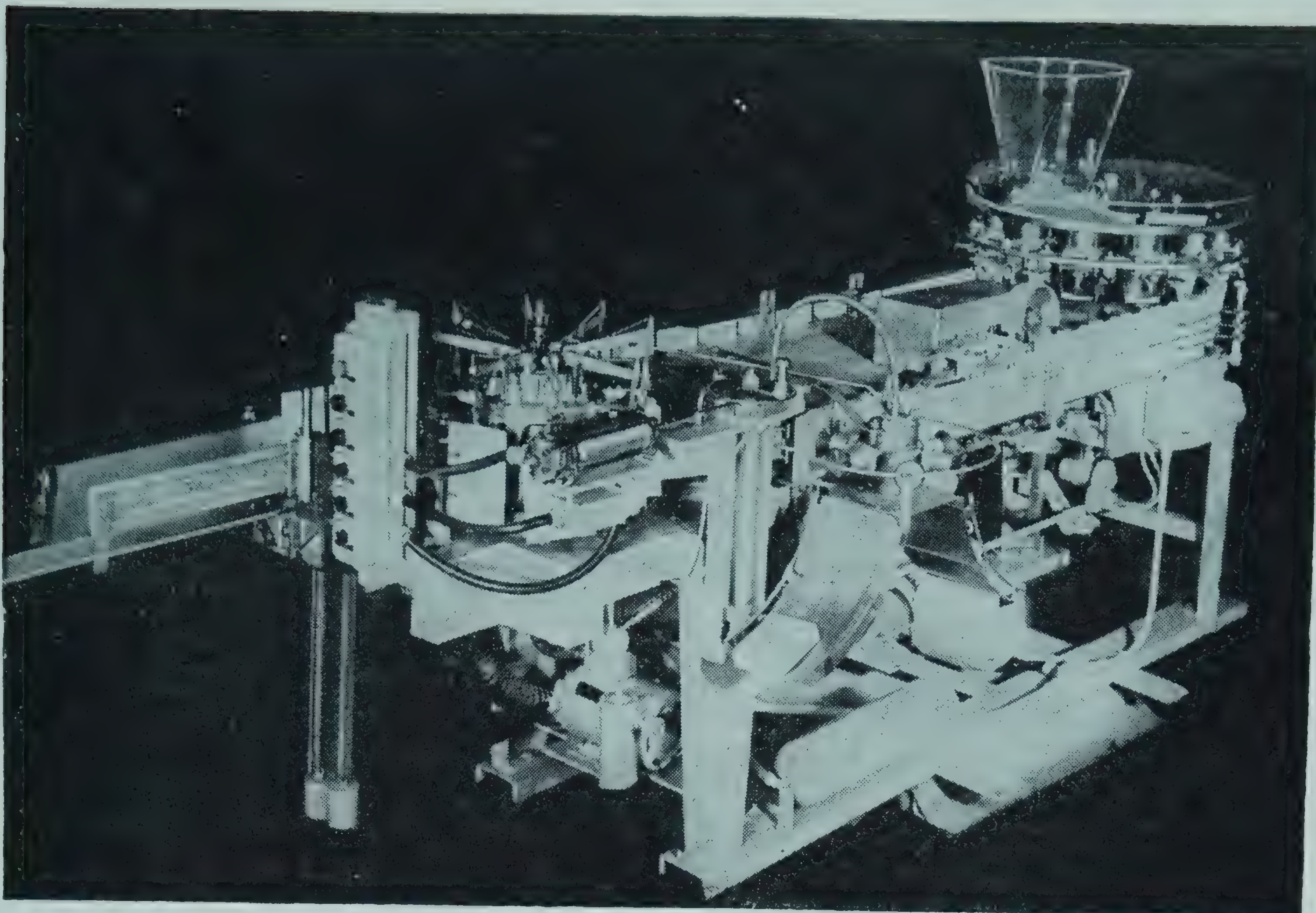


FIG. 118. High-speed, automatic packaging machine. (*Marathon Corp., Menasha, Wis.*)

that sank in the 38° salometer brine were discarded as being too mature for freezing.

The plants that vine their peas at the freezer argue that quality is improved by such practice as compared to that resulting with peas that are vined in the fields and subjected to 2 to 4 hr. delay before processing and freezing, since there is no opportunity for the drying on of viner juice, with subsequent difficulty of its removal by washing and no chance for fermentation or other bacterial action. On the other hand, it was said by several field men with whom this point was discussed that peas can deteriorate in quality on the vines, especially in hot weather, after cutting of the vines and during the delay between cutting in the field and vining at the freezer; also that it is necessary to truck about 5 tons of vines to obtain 1 ton of shelled peas; and trucking is costly.

The waste water from the various fluming, blanching, washing, and other operations in the Northwest is usually screened and pumped to a nearby field for use in the overhead spray irrigation of alfalfa or other forage or grass for livestock. One large plant irrigates a 200-acre field of alfalfa on which a rather large herd of Hereford cattle are pastured. The field is divided into several segments. While one is under irrigation, the others are free of water and are being pastured. Movable, large-diameter aluminum pipe carries the water in the irrigation system. During the fall

and winter months cattle can be fed on pea-vine ensilage that is packed in a pit silo during the pea-freezing season. As in the canning of peas, the waste vines in some cases are spread in the fields to sun-dry and are then baled and used as hay for feeding of cattle.

Most of the freezers in the Northwest and in California are operated under continuous inspection of the U.S.D.A., Agricultural Marketing Administration. See the paragraphs at the end of this chapter on this service.

The freezing-plant quality-control staff makes frequent tests of enzyme activity on samples taken from the line or on the packaged product. In one laboratory a sample of peas of 25 grams was disintegrated in a Waring blender with 100 cc. of water and strained. Then 2 cc. of this thin purée was added to 20 cc. of distilled water in a test tube. To the tube was added 1 cc. each of 0.08 per cent H_2O_2 (hydrogen peroxide solution) and of 0.5 per cent guaiacol oxidase indicator in 50 per cent ethyl alcohol. The contents of the tube were mixed and observed at the end of $3\frac{1}{2}$ min. Development of a reddish color was considered evidence of active peroxidase; absence of such color indicated destruction of the enzyme during blanching.

In California the peas are vined (shelled) in the fields and delivered to the plants in partially filled 50-lb. lug boxes. The various preparatory operations, packaging, and freezing are similar to those followed in the Pacific Northwest.

From the results of experiments at the University of California by Joslyn and Marsh and from surveys made by the author of products on sale, the conclusion is reached that some of the frozen-pack peas now being marketed are underblanched. In many cases peas from the retail markets in January to May (from the preceding season) were haylike in flavor and odor and had yellowed in color from loss of chlorophyll. It is realized that blanching severe enough to destroy peroxidase softens the peas considerably, but that is a far less objectionable condition than a hay flavor. This author is inclined to advise that peas be blanched sufficiently to destroy peroxidase, as judged by the usual tests.

Institutional-size cartons holding 25 lb. or more each of peas are stored individually. In this case it is better to freeze the peas outside the carton on screen trays, as previously mentioned, or in a continuous belt freezer, as freezing in the large containers is slow.

It is extremely important that the storage temperature be low, i.e., 0°F. or lower, since at higher temperatures deterioration in quality is apt to be serious. Also the temperature of the storage room should be uniform and should not fluctuate, since fluctuation results in sublimation of moisture vapor from the frozen product to the walls of the container, with consequent freezer burn and general decrease in quality.

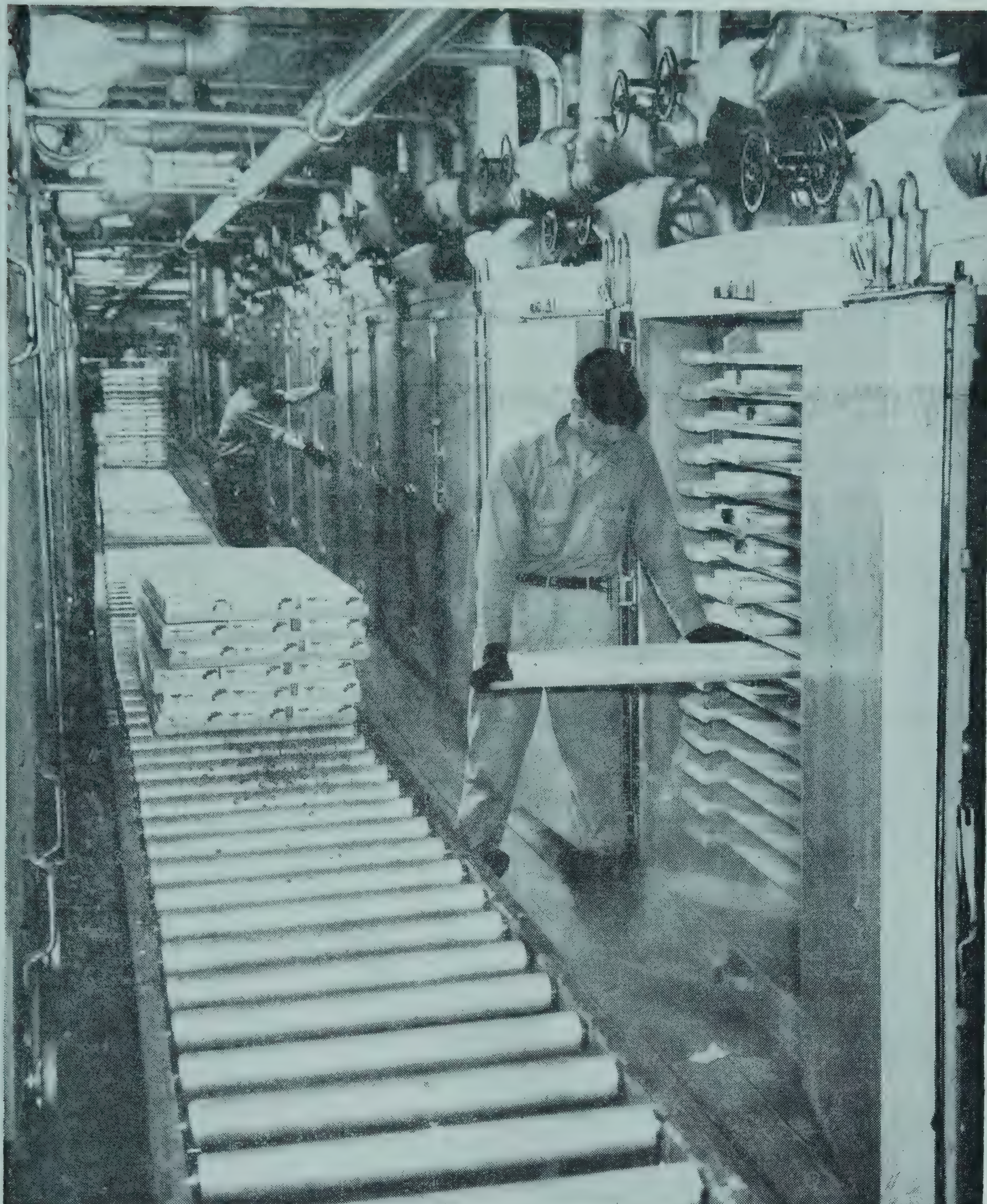


FIG. 119. Loading trays of cartons of prepared product into Amerio plate freezers. (*Seabrook Farms photo. Courtesy of Amerio Contact Plate Freezers, Inc., Union City, N.J.*)

Potatoes. Frozen French-fried are the most important of several frozen products made from white potatoes. The pack of all such products, chiefly French-fried, in 1953 was 70,694,174 lb. and in 1955 was 128,890,000 lb., according to *Quick Frozen Foods*.

For making French fries a variety of potato that gives a mealy rather than a waxy or soggy product should be used. In the West the Burbank

Russet (Idaho Russet) is preferred, and in Maine and other Eastern states the Katahdin appears to be superior to other common varieties. For this use the sugar content of the potatoes must be low; below 1 per cent, preferably below 0.5 per cent. If high in sugar content, the final product is apt to be soggy and marred by blackened spots. If potatoes are held in cold storage, the sugar content rises, and they must then be stored for 2 to 3 weeks at 70 to 75°F. to permit change of the excess sugar to starch or for it to be lost by respiration.

Kueneman and Havighorst (1955) have reported that the procedure followed in one large Western plant in preparing and freezing French-fried potatoes is about as follows: after removal of trash and stones the potatoes are washed, preheated in water at 120°F., peeled with strong lye solution at 205°F., drum-washed to remove loosened peels and lye; inspected and trimmed on a belt; and then graded for size. The larger sizes are used for French fries, and the small ones for other products. The peeled, trimmed potatoes are cut into strips about 3/8 by 3/8 or 3/8 by 1/4 in. in cross section. The strips are rinsed and screened to remove loose starch, "slivers" (narrow strips) and fines, which are utilized in other products. The strips are blanched in water in a pea-type blancher at 205°F. to partially precook and to improve uniformity of frying. They are then dried a short time in a continuous drier in a strong downward blast of air at 230°F. to reduce the load on the frier and give more uniform cooking.

They are next carried by oscillating screen conveyer through the first unit of a two-stage frier. The temperatures and the times in the two friers can be varied to suit the condition of the potatoes and the end result desired. Benes et al. used 360 to 365°F. for 4 min. in the first frier and 390°F. for 1 1/2 min. in the second. The strips emerge from the first frier fairly well cooked and with surface still almost white in color, and from the second completely cooked and of light golden-brown color. If frying is too slow, the interior of the strip will pull away from the "skin," and if too fast, the surface may be scorched and the interior only partially cooked.

The fried strips, according to Kueneman and Havighorst, are subjected on a traveling screen conveyer to a downward blast of air at about 315°F. to remove excess oil or fat from the surface. They are then cooled in a strong current of air in a cooling tunnel to about 90°F. They are frozen in a continuous belt-type freezing tunnel in a blast of air at −30°F., packaged, overwrapped, cased, and placed in freezing storage.

After frying and defatting as above, the potatoes should contain not more than 10 per cent of oil or fat; if it is much above this level, the product is apt to appear oil-soaked. According to Ziemba (1950), potatoes lose about 20 per cent of moisture during frying. Another author[1] states that they should contain about 50 per cent of moisture after frying. Ziemba also

[1] Anonymous, Swift and Co., mimeographed report.

states that in a large plant in Maine the potatoes are peeled by the steam-under-pressure process, described in Chapter 3. In other respects the operations are similar to those outlined above.

Fat must be added continuously during frying in order to replace that absorbed by the potato strips. Carlin et al. (1953) point out that the ratio of volume of fat in the frier to that of the potatoes should be small in order that the "turnover" (time required for fat added to equal that in the frier at the beginning of cooking) may be short. If it is too long, the fat becomes high in free fatty acid, develops off flavors and odors, and foams badly. For this reason they recommend that the frier be shallow and only enough fat used to permit satisfactory frying.

The frier may be heated directly by gas or other flame, according to Ziemba, or by special heat interchanger situated outside the frier, according to Kueneman and Havighorst. The oil is continuously circulated by pump during cooking. A screened trap in the line removes coarse particles of potato, etc. At regular intervals the oil is centrifuged or filtered to remove fines. If rancidification of the product occurs during storage, the use of an antioxidant such as B.H.A. may be needed in the fat used in frying.

The fragments from screening of the raw strips can be washed, blanched, shredded, mixed with onion or other flavoring, formed into "patties," packaged, and frozen. The consumer fries the patties before serving.

Diced potatoes are washed, blanched, cooled, flumed, dewatered, frozen, and packed. Frying is done by those who use the product. In *Food Engineering*, October, 1955, directions are given for preparing and freezing "potato puffs."

Sweet potatoes are frozen but are not of much commercial importance at present (1956). Woodroof and Atkinson (1944) recommend lye peeling, cooking in a retort, mashing or slicing, cooling, packaging, and freezing.

Other Vegetables. Cantaloupes and other melons are cut in half, seeds and "rag" removed, and the flesh cut by hand with special, spoon-shaped knives into small spheres ("melon balls"). These may be frozen with a small amount of dry sugar or in sirup. In experiments in the author's laboratory the sirup pack was preferred.

Some rhubarb is frozen for use in pies or sauce. The stems are cut into short lengths, washed, drained, packaged, and frozen without addition of sugar or sirup in most cases.

Other greens than spinach, such as chard, and mustard greens, can be prepared and frozen by the procedure given for spinach. Succotash, which may be a mixture of whole-kernel corn and green beans or Lima beans, is packed in considerable quantity. Various blends such as green beans, peas, corn, and diced carrots have been packed. They may be used in salads or as "main dishes."

Spinach. The demand for frozen spinach is good during the winter months

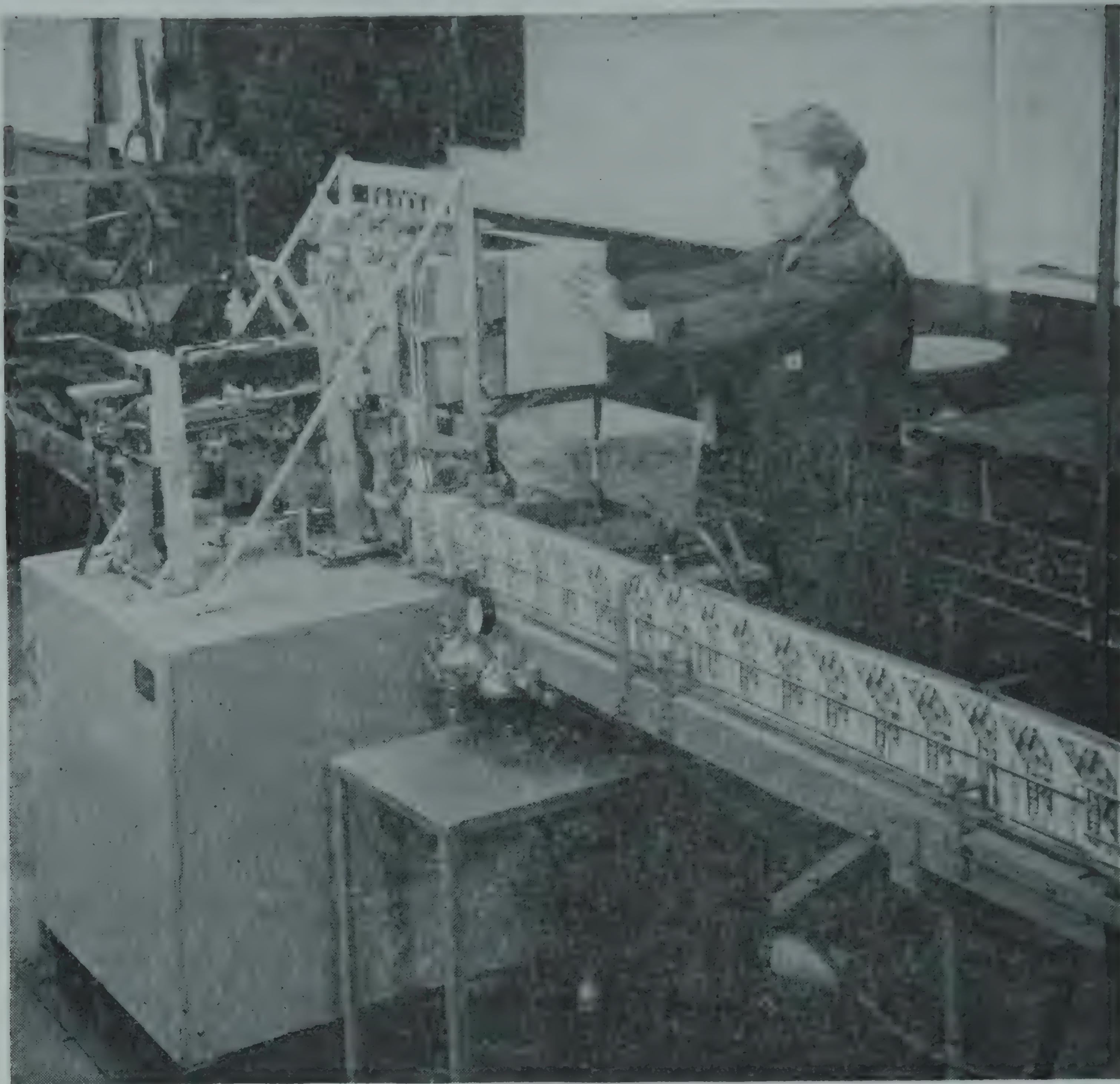


FIG. 120. Semiautomatic casing machine for cartons of frozen vegetables or fruits in plant of Western Frozen Foods Co., Inc., Watsonville, Calif. (*Western Canner and Packer.*)

in the Middle West and East when the fresh is unavailable or high in price. The recent packs, according to *Quick Frozen Foods*, were 91,463,973 lb. in 1952, 87,927,229 lb. in 1953, and 66,900,516 lb. in 1954. Of the 1954 output 40,889,405 lb. was packed in the West. The United States pack in 1956 was 81,443,000 lb.

Formerly, spinach became heavily infested with aphids and other insects in the fields, making it very difficult to pack a frozen product that would meet minimum requirements of the state and Federal food and drug regulations. In recent years, however, the leaves arrive at the plant with very few insects, as control by dusting with malathion, or other of the suitable newer insecticides has been very effective.

The spinach leaves are cut by a special harvester equipped with a mowing knife, reel to force the leaves against the knife, and an elevating draper that

carries the leaves into a dump truck or trailer driven beside the harvester (Figure 113). At the freezing plant the leaves are dumped into a large hopper or on a concrete slab and carried into the plant by belt or other type of conveyer. In most plants the leaves then pass through a dry cleaner, usually a revolving reel that retains the leaves but allows clods, small stones, pieces of leaves, and other small trash to pass through the screen. In some cases a preliminary sorting takes place before the dry cleaning. After dry cleaning the leaves are sorted at least once from slowly moving belts; often there are two such sortings of the raw leaves, in which yellow leaves, weeds, and other unfit or foreign material is removed. In some plants the leaves are first washed in a detergent bath; in others the first washing is in water only. The leaves are carried through a long shallow tank of water by paddles or other conveying device, and very heavy sprays of water are played on the surface of the water and on the floating leaves. A washing in heavy sprays of water then follows the tank washer. In some plants a third spray washing is given. In at least one California plant the leaves are given a short preliminary blanch in hot water before the final washing. The washed leaves are usually sorted before blanching.

While for canning, spinach is blanched at about 170°F. in water to better retain the green color after retorting, the leaves for freezing are usually blanched in live steam 2½ to 3 min., or long enough under the plant's conditions to inactivate peroxidase enzyme since the frozen leaves retain their color well. The leaves are cooled by sprays of water and by fluming to the packing stations.

The leaves are packed by hand by weight into retail cartons of 10- to 12-oz. capacity or into larger cartons for the institutional trade. The women at the packing stations inspect the leaves as they are packed and discard any unfit leaves and other undesirable material that may have escaped previous sorters. Packing is done usually from a slowly moving belt. Some of the leaves are allowed to pass over the end of the belt, usually the less perfect ones, and these are coarsely ground or chopped and packed by automatic fillers into cartons. After sealing and overwrapping, the cartons are quick-frozen, as previously described for other products, and stored at −5°F. or lower.

Laboratory control includes checking the net contents of frequent samples of the packed product; determination of quality as judged by color, effectiveness of sorting, freedom from defects, and by other factors; and a very careful examination for presence of aphids, worms, or other insects. As is the case with most other vegetables, spinach is usually packed in Western plants under Federal inspection and certification of the Agricultural Marketing Administration of the U.S.D.A.

Tomatoes. To date attempts to preserve tomatoes in frozen pack have been unsuccessful, since they soften very badly on thawing and are then

FIG. 121. Automatic wrapping machine for retail-size cartons. (*Hayssen Mfg. Co., Sheboygan, Wis.*)

similar to canned tomatoes in texture. If the fruit could be maintained in firm condition suitable for use in salads, there would undoubtedly be a greater market for it.

Uncooked tomatoes and uncooked tomato juice develop a bitter taste and off flavor in freezing storage. Juice made from tomatoes heated to 190 to 212°F. keeps perfectly in freezing storage and is superior to the canned in flavor and aroma.

Cooking Frozen-pack Foods. Because freezing softens the texture of vegetables and fruits, frozen-pack products require much less cooking than the corresponding fresh products. Frozen-pack fruits are often served without cooking, either in the frozen condition or soon after thawing. However, large quantities of frozen-pack berries and lesser quantities of frozen apricots, peaches, and apples are used in making pies, preserves, jams, jellies, and other cooked products. Frozen-pack barreled strawberries are very suitable for use in preserves and ice cream, and preservers and ice-cream factories are the principal purchasers. The suitability of berries for jelly making is not materially altered by freezing storage, according to Joslyn and Marsh (*University of California Agricultural Experiment Station Bulletin* 551), as the pectin content is only slightly diminished. The frozen fruits are treated similarly to the fresh in utilizing them for preserves, jellies, and jams.

Vegetables are placed into boiling water, seasoned to suit, and cooked a short time. Overcooking is the principal danger, as it gives a soft, mushy, or soggy product of poor flavor and color. Cook only long enough to render the product of desirable texture and flavor; for peas, for example, this will usually be not more than 5 min. at the boiling point. When they are properly cooked, frozen peas, corn, cut or on the cob, string beans, Lima beans, and spinach are practically identical with the cooked fresh products. Do not

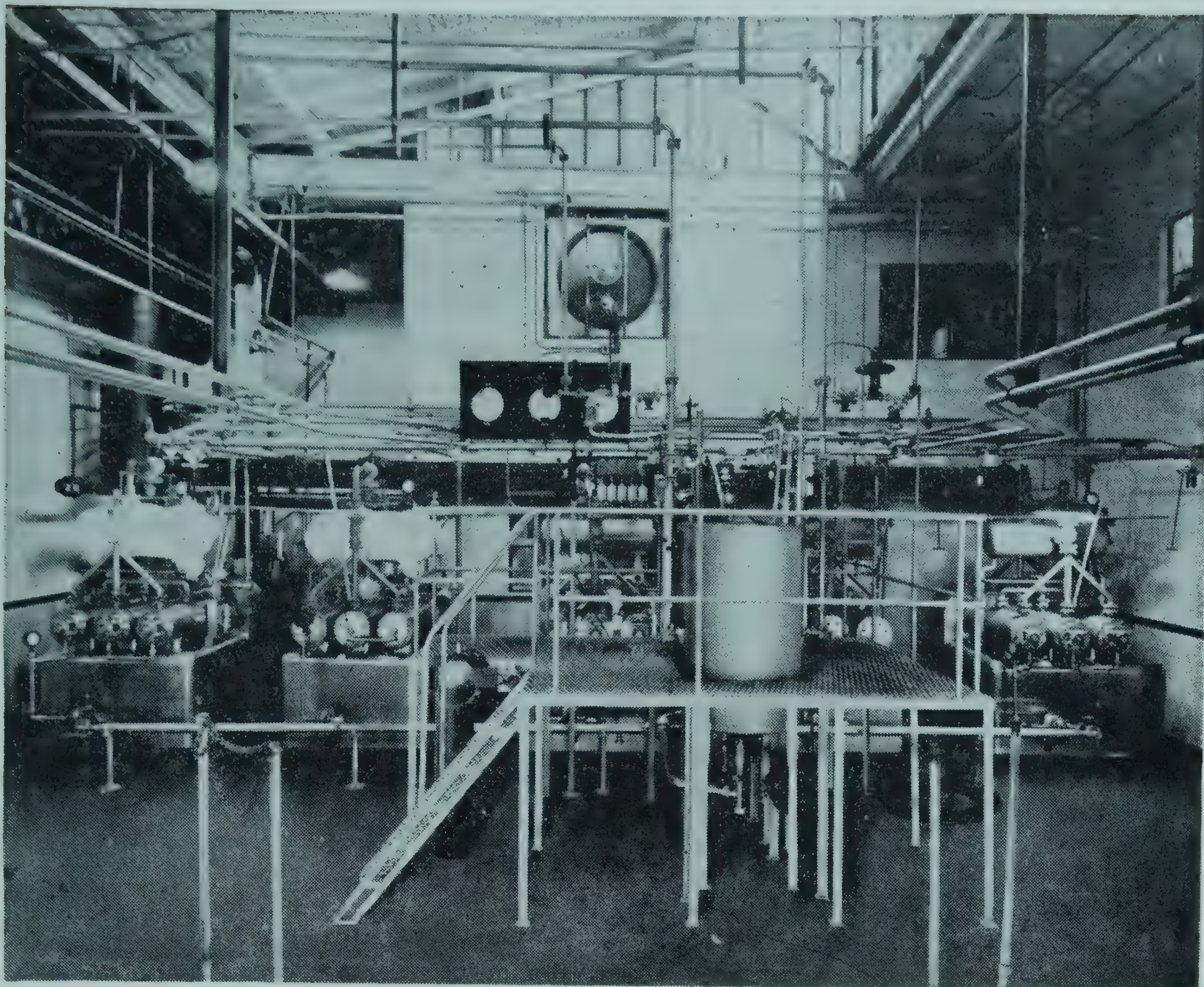


FIG. 122. Votator Continuous Slush Freezing Apparatus for citrus concentrates and other products. (*The Girdler Co., Votator Division, Louisville, Ky.*)

cook the vegetable in a large volume of water. In order to retain and utilize flavor and soluble nutrients, cook in a very small amount of water, and do not discard it after cooking is completed.

Shipping Frozen Foods. Often frozen foods are shipped from the far West to cities on the eastern seaboard, involving a journey of a week or more. During this period the product must be maintained in a frozen condition. Also, as is the case for the storage of frozen foods, the temperature during transit should not fluctuate very much.

At present the frozen products are usually shipped in ordinary refrigerator cars by rail. The ice bunkers are filled with a mixture of crushed ice and coarse salt before the car is filled with the product. The frozen product also rapidly reduces the temperature of the car and provides a large reservoir of cold. During loading a canvas "tunnel" covering the passageway from the warehouse to the car door is usually set up to protect the products from direct rays of the sun or from rain or snow. Loading is as rapid as possible.

During transit more ice and salt are added to the bunkers at icing stations en route. With care and attention the frozen foods will arrive in good condition at destination. If, however, re-icing is neglected or is inadequate,

or if the train is delayed several days between icing stations, a rise in temperature sufficient to cause thawing and serious deterioration may ensue.

Much frozen produce is also shipped by refrigerated truck with ice and salt. A better method, of course, is use of mechanically refrigerated cars and trucks in which a Freon or other efficient refrigerating system has been installed. This is automatically controlled at the desired temperature, and icing is unnecessary. Eventually more of these cars and trucks will be available with great benefit to the frozen-foods industry.

Handling at Destination. Frozen fruits and vegetables on arrival at destination should be unloaded promptly and placed in storage in a freezing-storage warehouse maintained uniformly at 0°F. or lower until distributed to the retail markets or to institutional users. In some cities special freezer-storage warehouses owned and operated by wholesalers specializing in this service have been built. This would appear to be a good innovation.

Delivery to the retailer should be in refrigerated trucks maintained at as near 0°F. as possible.

At the retail store the frozen foods must be placed in the store's freezer cabinet at once and must not be allowed to stand on the floor or on top of the cabinet an hour or more until the clerk gets around to unpacking and storing the packages.

The retailer's cabinets should be in good working order at all times and should be of the type equipped with freezer coils that come to near the top of the freezing cabinet, since the top layer of packages is the critical one. During the rush hours the cabinet may be open more than half the time; in fact, the cover may be open for an hour or more. Consequently, unless refrigeration is maintained at this top layer as well as in the bottom of the cabinet, thawing with serious loss in quality may ensue. Specially constructed cabinets that remain open continuously without thawing of packages in the top layer are in general use (Figure 123).

Retailers should be instructed never to allow the frozen foods to thaw. Some are inclined to overlook this extremely important requirement.

Care in the Home. The average home refrigerator should not be relied upon to keep packages of frozen foods indefinitely, even in the freezing compartment. If, however, the home has a "deep-freeze" cabinet of satisfactory make, the packages may be kept about as well as in a freezer warehouse, provided the freezer is in good working order and the owner does not place unfrozen foods in it.

PRECOOKED FROZEN FOODS

There is at present a great deal of activity in the packaging and freezing of cooked foods. Examples are chicken à la king, corned-beef hash, French-fried potatoes, oyster stew, clam chowder, pies, complete meals on alu-

minum trays, Italian-style sauces, chili beans, and concentrated soups. While these and many other foods are also canned, it is true that the frozen products are usually superior to the canned in flavor. Usually they are packed slightly on the undercooked side, with prominent directions on the label to cook the product before serving.

All such foods should be heated to or near the boiling point on the stove or in the oven before serving, in order to eliminate all danger of food infection or poisoning, for the following reasons: Precooked foods are excellent bacterial media; and if the packer does not freeze them promptly, if they thaw in transit or in the retail store, or if they are allowed to thaw and stand several days in the home, bacterial spoilage or growth may ensue. Also, there is always the remote danger of food-borne infections from typhoid, amoeba, or paratyphoid carriers among the workmen in the freezing plant.

Consequently, consumers should be educated to heat precooked frozen foods thoroughly after thawing. The label on the product should carry such instruction in heavy boldface type. If proper precautions are taken, precooked frozen foods should have a good future.

Frozen cooked sieved fruits and vegetables for use as baby foods, in soups, etc., have been studied by Joslyn and Hohl of the University of California and are highly recommended by them to the industry. Here again the mother or housewife must be advised to heat the food thoroughly before using.

A great deal remains to be done on the behavior of various foods and food components in precooked foods during freezing. For example, ordinary starch when cooked and made into a sauce or pudding will often become spongy and tough on freezing and thawing. Some sauces curdle on freezing and thawing. Some meat products are apt to toughen or become stringy, and so on. Therefore the freezer proprietor should thoroughly test the behavior of his precooked foods not only on freezing but after prolonged storage and thawing. Some products, such as piecrust, that contain fats or oils may rancidify rapidly in freezing storage. A relatively nonrancidifying fat may be indicated, or an antioxidant may be necessary.

Some flavoring materials behave more satisfactorily than others in frozen cooked foods.

Frozen precooked dinners are quite popular at present. They are usually packed in shallow aluminum trays that are overwrapped with lithographed paper. Under the paper is usually aluminum foil as an overwrap in contact with the precooked foods and tray. To prepare for serving, the paper overwrapping is removed and the tray heated in an oven at about 450°F. with the aluminum foil overwrap in place. In some cases the foil is removed after the tray has been heated about 15 min. and an additional 10 to 15 min. heating is given to make the meat crisp. Various combinations of meat and

vegetables are made. A common one is fried chicken, mixed peas and diced carrots, and a serving of mashed potatoes. Precooked meals are very extensively used by the military forces, particularly by the air forces.

Fruit pies are packed and frozen by many establishments. They are available in precooked form and in the raw condition. According to Woodroof and Shelor the raw pies, i.e., raw crust, to be baked by the consumer, are more satisfactory in quality than the prebaked pies, although the fruits kept better if heated sufficiently to destroy oxidizing enzymes before placing in the raw crust. Hohl (1944), Hohl and Smith (1944), and Hohl, Buck, and Rosoff (1949) found that sieved baby foods and precooked sieved purées kept perfectly for more than a year at 0°F.

They also state that some precooked foods, including cooked fruits, fruit cakes, cookies, and low-fat, lightly seasoned beef or chicken stew, and combinations of meats, fish, and poultry with vegetables cooked with moist heat and covered with gravy or sauce or other liquid kept well for 6 to 9 months. Most fully cooked vegetables, fried chicken or fish, barbecued chicken or pork, doughnuts, or other food products cooked in deep fat and packed dry kept for only a few weeks in freezing storage before becoming stale or rancid in flavor. An antioxidant might prevent this change.

The keeping quality of the flavor of most precooked frozen foods was usually inferior to that of the same foods uncooked. The flavor and odor of certain added spices and flavorings decreased greatly in freezing storage. Rancidifying of fats is a common form of deterioration in freezing storage. Precooked vegetables covered with a sauce or other liquor kept approximately twice as long in respect to flavor as those packed without liquid. Rasmussen, Esselen, and Fellers found that baked apples retained their flavor and aroma for at least a year. Hanson of the U.S.D.A. has found that sauces and gravies made with ordinary starch or flour break down badly during freezing storage and subsequent thawing but are much more stable if made with waxy starch or waxy flour such as made from waxy corn varieties. For a comprehensive presentation by 20 specialists on various phases of frozen precooked foods, see Q.M. Food and Container Institute symposium entitled "Precooked Frozen Foods," Chicago, 1955 (see references).

LOCKER FREEZERS

Many locker storage freezers have been built, chiefly in small cities and towns in farming areas, although they are being established to a limited extent also in the large cities. They are operated as independent establishments in most cases, but also may be located in a large commercial ice and cold-storage plant, or in connection with a large country store or butcher shop.

There are more than 5,000 locker plants in the United States. They vary in size from 200 or less to 1,200 or more lockers. The plant consists of a chill room, or several of them, in which carcasses of sheep, hogs, beef animals, deer, etc., are hung for several days to be chilled and aged; a cutting and wrapping department equipped with modern mechanical meat-cutting and -grinding equipment; a quick freezer at about −30°F., for freezing the packaged meats, fruits, and vegetables before storage; lockers in a room maintained at 0°F.; and an overflow freezing-storage room for temporary freezing storage of patrons' produce. Most locker plants are equipped also to salt or brine-cure meats and to smoke meats and fish.

Lockers, although variable in size, usually hold from 100 to 200 lb. of meat; somewhat less weight of fruits or vegetables. Many patrons rent two or three lockers. The rental charge will vary with the size of locker and location of the plant. The charge for cutting and wrapping meats is variable, but usually is less than 7 cents per pound in the plants in the author's neighborhood.

The locker-plant operator will age, cut, and wrap meats of animals slaughtered by the patron and freeze and store the wrapped meats.

Usually in farming communities the animals are grown and slaughtered by the locker patrons. In large cities the patron may purchase meat in bulk at more or less wholesale prices from the locker operator. Similarly, many locker plants purchase packaged frozen vegetables, fruits, and fish in wholesale lots and sell them to their locker patrons at relatively low price for storage in their lockers.

Most locker plants pluck and dress patrons' chickens and other poultry and may in addition purchase the live poultry and freeze it for sale at less than the usual retail price to patrons. Some plants also render lard for patrons, and most locker operators will grind meats for hamburger or sausage.

Fruits and vegetables are usually prepared and packaged by the grower or other patron and brought promptly to the plant for quick freezing and storage. The usual locker plant does not have space for the preparation of fresh fruits and vegetables and concentrates its facilities instead on meats.

Plans can be had for locker plants from suppliers of refrigerating equipment and from several colleges of agriculture.

Meats should be wrapped in moistureproof or moisture-vapor-proof material. Ordinary butcher-shop wrapping paper allows desiccation of meat wrapped in it, but it is a good overwrap for meats wrapped in pliofilm, moistureproof cellophane, or aluminum foil. In the author's experiments aluminum foil proved to be an excellent wrap for meats. Packages for fruits and vegetables must be liquid-tight and as near moisture-vapor-proof as possible. Heat-sealable plastic bags or such liners in cartons are satisfactory. Also, there are available heat-sealable cartons and re-usable

FIG. 123. Frozen-food cabinets for retail distribution of frozen foods. (*Tyler Refrigeration Corp., Niles, Mich.*)

waxed cartons, jars, and cans for locker or home-freezer use. The locker operator furnishes such containers and wrapping materials at low cost. Desiccation of meats and other foods in poor packages is a principal cause of deterioration in storage.

In preparing vegetables for freezing the same principles apply as in commercial practice described earlier in this chapter. Only fresh vegetables of best quality should be used. Overmaturity is the principal defect to be avoided. Thorough blanching of vegetables is necessary.

Peaches should be pitted and peeled and sliced, as outlined for commercial practice, and should be packed in sucrose sirup consisting of about 1 cup of sugar to 3 of water. Addition of 1 teaspoon of ascorbic acid to 2 to 3 qt. of sirup will greatly retard darkening and deterioration. Apricots are pitted and sliced; strawberries are cut in half; other berries are packed whole; plums are pitted and halved; and pears peeled and sliced. Berries are usually packed with dry sugar, 1 cup to about 5 cups of berries. Juices are prepared as outlined in Chapter 12.

The locker operator must maintain a neat and clean plant and equipment and should provide conveniences for his patrons, such as baskets to carry frozen packages from the locker room and several warm coats to

protect women patrons from the cold of the locker room. The locker room should be held at not above 0°F. since frozen foods deteriorate fairly rapidly at higher temperatures. Wrapping and packaging materials must not impart off flavors and odors to the frozen products.

HOME AND FARM FREEZERS

Freezers for home use are of two general types: (1) the top-opening bin type and (2) the side-opening shelf type. The second type is more convenient but loses more "cold" when the door is opened. Most home refrigerators have a small freezing compartment, but as Vera Greaves Mrak points out, these compartments maintain only a temperature of about 15°F.; consequently she advises that they be used only for temporary storage, for example, 2 to 4 weeks. Although the foods are in the frozen state at 15°F., they deteriorate fairly rapidly in quality.

Often a home freezer will be profitable on the farm as a means of saving surplus fruits, vegetables, and chickens. For the city dweller it may serve chiefly as a means of providing a varied menu and a supply of ready-to-use vegetables, fruits, and meats; but after all things are considered, it may not be a profitable investment financially.

In addition to freezers for installation indoors, various sizes of walk-in freezers for farm use can be bought, or they may be built from plans available from several state colleges of agriculture, among them the Agricultural Extension Division of the University of California, College of Agriculture.

Dr. V. G. Mrak, *California Agricultural Experiment Station Circular* 420, states that 1 cu. ft. of freezer space holds about 40 lb. of frozen fruit, or about 25 to 30 lb. of frozen vegetables, or about 35 to 40 lb. of meat; or it will hold about 40 pint cartons each holding about 1 lb. of fruit and sirup, or 10 to 12 oz. of vegetables.

The freezer should maintain a constant temperature of 0°F. or lower, preferably -5 to -10°F. Dr. Mrak advises that users of home-size freezers should not attempt to freeze per 24 hr. more wrapped or packaged food than equal to 5 per cent of the unit's capacity. If much more than this amount of produce at room temperature is placed in the unit, the temperature may rise to the point at which serious deterioration of the contents of the freezer will occur. If larger amounts are to be stored per 24 hr., they should be frozen at a locker plant.

Fruits and vegetables are prepared for storage in the home freezers as described earlier in this chapter for commercial production or for locker storage (see preceding section).

Full directions for the plucking, dressing, packaging, and freezing of poultry are given in the bulletin on home freezing by Vera Greaves Mrak, mentioned earlier in this section.

In cooking frozen vegetables for serving, the most frequent error is in overcooking. Place only a small amount of water in the pan, cover the pan, and bring water to boiling; cook only until tender. Vegetables are apt to lose quality if slowly thawed in air before cooking, the exception being corn on the cob, which should be thawed before cooking.

Home-prepared dishes such as stews, casserole dishes, and baked apples may be stored, but there is little need for storing complete meals.

Fruits should be thawed quickly in the package, as by placing the package in cold water. Quick thawing minimizes darkening of the color and changes in flavor. Fruits may be served partially thawed.

Some precooked foods change seriously in texture on freezing and thawing; sauces made with ordinary starch, for example, will curdle. If, however, waxy corn starch is used, curdling will not usually occur.

Packages should be labeled prominently for easy identification. Frozen foods should be used, not stored and forgotten; every product has a maximum storage life, in some cases less than 6 months. Use only foods of good quality for freezing, as freezing cannot improve the quality. For further details see references at the end of the chapter. Finally, the question of "to buy or not to buy a home freezer" is one that each family must decide for itself; there is no standard answer.

Continuous Federal Inspection. Many freezers, canneries, and other fruit and vegetable processing plants operate under continuous inspection and U.S. quality-grade certification by the U.S.D.A., Agricultural Marketing Administration (also known as the Agricultural Marketing Service). For the Western states the regional offices and laboratories are located in San Francisco. National offices are in Washington, D.C.

The service is on a voluntary basis and is self-supporting; i.e., it is not financed from tax funds, but by moderate fees paid by the freezer or other processor under inspection. Application for the service may be made to the nearest field office or the regional office.

The inspectors are usually graduates of a university or college of recognized standing and are under civil-service regulations. A charge is made for the inspector's time at a specified rate per hour, and additional small fees are made for sampling each lot of product. Procedure for filing an appeal concerning the U.S. quality grade assigned to a given lot of product by the inspector is detailed in the regulations.

Each lot must be coded in such a manner that it can be identified easily. The inspector, after careful inspection, assigns a U.S. quality grade to each lot, and the packer may state on his label that the product is of a certain U.S. grade, as, for example, U.S. Grade A, and is packed under continuous U.S.D.A. inspection. An inspector is in the plant at all times during plant operating hours and has at his disposal a laboratory and necessary laboratory equipment.

Detailed specifications have been published for all the fruit and veg-

etable products that are at present under such inspection. These are revised frequently. A full account has also been published of the organization of the service and its method of operation. This statement and the specifications for each product may be obtained from the U.S.D.A., Agricultural Marketing Administration.

Typical U.S. Grade Specifications. While space limitations will not permit their full presentation here, the following very brief outline of the more important specifications for quality grades for peas may be of value in indicating the general nature of the requirements for this and other frozen products.

Frozen peas are defined as the product made from "immature seed of the common garden pea (*Pisum sativum*) by shelling, washing, and precooking (blanching) and are frozen and stored at temperatures necessary for the preservation of the product."

U.S. Grade A, or Fancy, frozen peas must be of similar varietal characteristics, practically free of defects, tender, of normal flavor and odor, and score not less than 90 points in accordance with the scoring system of the service.

For U.S. Grade B, or Extra Standard, the wording is similar except that the qualifying adjective "reasonably" is inserted and the score must be not less than 80.

For U.S. Grade C, or Standard, the adjective "fairly" replaces "reasonably." U.S. Grade D, or Substandard, frozen peas are those that fail to meet the requirements for Grade C.

The scoring system for peas is as follows:

	Points
Color	20
Absence of defects	40
Tenderness and maturity	40
Total	100

Detailed directions are given in the specifications for assessing numerical values for each of the factors. For example, to score the necessary 36 to 40 points on "tenderness and maturity" for Grade A, not more than 10 per cent by count of the peas with skins removed may sink within 10 sec. in a brine of 13° salometer. For U.S. Grade B the maximum number that may sink is 15 per cent, and for Grade C, 16 per cent.

Directions are also given for arriving at numerical values for absence of defects and color.

REFERENCES

General

Advisory Board on Quartermaster Research and Development: "Precooked Frozen Foods: A Symposium," Quartermaster Food and Container Institute, Chicago, December, 1955. Contains 14 papers on this subject.

ANDERSON, E. E., and ESSELEN, W. B.: Factors influencing the quality and texture of frozen blueberries, *Food Technol.*, **8**(9), 418–422, September, 1954.

AREF, M., SIDWELL, A. P., and LITWILLER, E. M.: The effects of various sweetening agents on frozen strawberries for preserve manufacture, *Food Technol.*, **10**, 293–297, 1956.

ARENGO-JONES, R. W., ET AL.: The preservation of fruits and vegetables by freezing, *Can. Dept. Agr. Pub.* 591, *Tech. Bull.* 12, 1937.

"Ascorbic and Citric Acids in Frozen Foods," Chas. Pfizer and Co., Inc., New York, 1950.

BAUERNFELD, J. C., and SIEMERS, G. G.: Adding ascorbic acid to peaches before freezing, *Food Inds.*, **17**(7), 79–81, 1945.

BEATTIE, R. W., HARTER, L. I., and WADE, B. L.: Growing peas for canning and freezing *U.S. Dept. Agr. Farmers' Bull.* 1920, December, 1942.

BEDFORD, C. L., and ROBERTSON, W. F.: Effect of pretreatment on quality of frozen blueberries, *Quick Frozen Foods*, **17**(1), 53,132, August, 1954.

BENES, C., and CARLIN, G. T.: The preparation of French fried potatoes, *Natl. Restaurant Assoc. Tech. Bull.* 100, Chicago, August, 1949.

BOGGS, M. M., CAMPBELL, H., and SCHWARTZE, C. D.: Factors affecting the decomposition of frying fats, *Food Research*, **7**, 272–287; **8**, 140–142, 1942–1943.

CARLIN, G. T., HOPPER, R. P., and BUCKWOOD, B. M.: Some factors affecting the decomposition of frying fats, *Food Technol.*, **8**(3), 161–165, 1954.

COLE, G. M.: Concentrates for lemonade, *Food Technol.*, **9**(1), 38–45, 1955.

CRUESS, W. V.: Improved method of packing frozen peas, *Quick Frozen Foods*, August, 1948. See also: Sugar improves frozen peas, *Fruit Products J.*, September, 1949.

———: Studies of frozen food samples bought in the open market, *Food Freezing*, May and June, 1946.

———: Blanching and cooling for frozen pack, *Fruit Products J.*, **25**(5), 134, 135, January, 1946.

——— and MARSH, G. L.: Frozen pack ripe olives, *Fruit Products J.*, **12**(6), 176, February, 1933.

——— and OVERHOLSER, E. L.: Freezing fresh fruits in cans, *Canning Age*, February, 1925, pp. 97–99.

———, ———, and BJARNASON, S. A.: Storage of perishable fruits at freezing temperatures, *Univ. Calif. Agr. Expt. Sta. Bull.* 324, 1920.

DIEHL, H. C.: Report of director of Refrigeration Research Foundation, Colorado Springs, 1951. See also reports for 1952–1957.

———, CAMPBELL, H. C., and BERRY, J. A.: Some observations on freezing preservation of Alderman peas, *J. Food Research*, **1**, 61–71, 1936.

———, MAGNESS, J. R., GROSS, C. R., and BONNEY, V. B.: The frozen pack method of preserving berries in the Pacific Northwest, *U.S. Dept. Agr. Tech. Bull.* 148, 1930.

Expanding frozen fruit pie sales (blueberry), *Quick Frozen Foods*, **19**(2), 50, 168, September, 1956.

FENTON, FAITH: Cooking of frozen foods and their nutritional value, *Cornell Univ. Bull. for Home Makers* 628, 1943.

Food Machinery Corp., Engineering Dept.: Flow diagram for the production of frozen French fried potatoes, San Jose, California, 1956.

"Frozen French Fried Potatoes," Swift and Co., Chicago, 1956.

HOHL, L. A.: Experiments prove value of freezing baby foods, *Quick Frozen Foods*, August, 1944.

———, BUCK, P., and ROSOFF, H.: Further studies on frozen fruit and vegetable purées, *Food Technol.*, **3**(3), 100–110, 1949.

——— and SMITH, MILDRED: Comparison of vitamin content and palatability of frozen, canned and dehydrated vegetable purées, *Fruit Products J.*, **24**(2), 54–56, 62, October, 1944.

———, SWANBURG, J., DAVID, J., and RAMSEY, R.: Cooling of blanched vegetables and fruits for freezing, *Food Research*, **12**(6), 484–495, 1947.

JOSLYN, M. A.: Use of liquid sugars in freezing of apricots, peaches and nectarines, *Food Technol.*, **3**(1), 8–14, 1949.

——— and HOHL, L. A.: The commercial freezing of fruit products, *Univ. Calif. Agr. Expt. Sta. Bull.* 703, 1948.

KALOYEREAS, S. A.: The effect of various methods of blanching on ascorbic acid and soluble solids in cauliflower and spinach, *Fruit Products J.*, **26**(5), 134–136, 1947.

KIRKPATRICK, M. E., HEINZE, P. H., CRAFT, C. C., MOUNTJOY, B. M., and FALATKO, C. E.: French frying quality of potatoes as influenced by cooking methods, storage conditions and specific gravity, *U.S. Dept. Agr. Tech. Bull.* 1142, 1956.

KUENEMAN, R. W., and HAVIGHORST, C. R.: How to unit-engineer a line operation, *Food Eng.*, **27**(5), 86–89, 212, 118–121, May, 1955. Includes frozen French fried potatoes.

LEE, F. A.: Objective methods for determining the maturity of peas, with special reference in the frozen product, *N.Y. State Agr. Expt. Sta. Tech. Bull.* 256, March, 1941.

MACKINNEY, G.: Immersion freezing in liquid nitrous oxide, *Food Inds.*, **18**, 667–669, 816–822, 1946.

MORRIS, T. N., and BARKER, J.: Preservation of fruits and vegetables by freezing, *Rept. Food Invest. Bd., Dept. Sci. Ind. Research Great Britain*, 1930, pp. 126–130; 1931, pp. 129–133; 1932, pp. 92–94. Also *Great Britain Food Invest. Bd. Leaflet* 2, 1932.

"The New Canco Frozen Foods Container," American Can Co., New York. Describes fiber can for frozen foods.

PERRY, W. J., and CRUESS, W. V.: Observations on sugar penetration in frozen fruits, *Quick Frozen Foods*, **15** (11), 55–57, June, 1953.

PHILLIPS, W. R.: Frozen food packaging tests, *Can. Food Inds.*, December, 1947.

PRESPER, MARY L.: Review of literature on retention of nutrient content in fresh and "quick frozen" foods, *Quartermaster Corps, Research and Devel. Branch, Spec. Rept.*, Chicago, February, 1946.

TOBIN, R. B.: How a Maine packer freezes French fried for 14 brands, *Quick Frozen Foods*, **13**(8), 104–105, 176, 1951.

TRESSLER, D. K., and EVERS, C. F.: "The Freezing Preservation of Foods," Avi Publishing Co., New York, 1936 (revised 1956).

WIEGAND, E. H.: Preservation of fruits and vegetables by freezing, *Ore. Agr. Expt. Sta. Bull.* 116, 1936.

WOODROOF, J. G.: Preserving foods by freezing, *Georgia Agr. Expt. Sta. Bull.* 233, 1944.

——— and ATKINSON, I. S.: Preserving sweet potatoes by freezing, *Georgia Agr. Expt. Sta. Bull.* 322, 1944.

ZIEMBA, J. V.: Making French fried on a continuous line, *Food Inds.*, **23**, 113–115, May, 1950.

Variety Tests

BURK, E. F.: Freezing studies with sweet corn varieties in Eastern Washington, *Proc. Am. Soc. Hort. Sci.*, **35**, 725–727, 1937.

CALDWELL, J. S., LUTZ, J. M., CULPEPPER, C. W., and MOON, H. H.: Corn: suitability for freezing of thirty-five varieties, *Canner*, July 18, July 25, Aug. 1, Aug. 8, 1936.

——— and MOON, H. H.: Comparative studies of varietal suitability of peas, Lima

beans, snap beans and sweet corn for freezing preservation, *U.S. Dept. Agr. Tech. Bull.* 731, 1940.

KNOWLES, D., GROTTODEN, O., and LONG, T. E.: The comparative suitability of varieties of green beans, Lima beans, wax beans, sweet corn and peas for freezing preservation, *N. Dakota Agr. Expt. Sta. Bull.* 322, 1943.

MOON, H. H., CALDWELL, J. S., and LUTZ, J. M.: Peas: suitability for freezing purposes of 18 varieties, *Canner*, July 4 and 11, 1936.

———, ———, ———, and CULPEPPER, C. W.: Snap beans, comparative suitability for freezing purposes of 14 varieties, *Canning Age*, **17**, June and July, 1936.

Microbiology

BERRY, J. A.: Destruction and survival of microorganisms in frozen pack foods, *J. Bacteriol.*, **26**(5), 459–470, 1933.

STRAKA, R. P., and JAMES, L. H.: A health aspect of frozen vegetables, *Am. J. Public Health*, **22**, 473, 1932; **28**, 700, 1933.

TANNER, F. W.: "The Microbiology of Foods," 2d ed., Garrard Press, Champaign, Ill., 1944.

WALLACE, G. L., and PARK, S. E.: The behavior of Clostridium botulinum in frozen fruits and vegetables, *J. Infectious Diseases*, **52**, 150–156, 1933.

Enzymes and Control of Enzyme Activity

ARIGHI, A. L., JOSLYN, M. A., and MARSH, G. L.: Enzyme activity in frozen pack vegetables, *Ind. Eng. Chem.*, **28**, 595–598, 1936.

BUCK, P. A., and JOSLYN, M. A.: Broccoli processing: accumulation of alcohol in underscalded frozen broccoli, *Agr. and Food Chem.*, **1**(4), 309–312, 1953.

ESSELEN, W. B., and ANDERSON, E. E.: Thermal destruction of peroxidase in vegetables at high temperatures, *Food Research*, **21**, 322–326, 1956.

FARKAS, D. F., GOLDBLITH, S. A., and PROCTOR, B. E.: Stopping off-flavors by curbing peroxidase, *Food Eng.*, **28**(1), 52–54, January, 1956.

JOSLYN, M. A.: Report on peroxidase in frozen vegetables, *J. Assoc. Offic. Agr. Chemists*, May, 1949, pp. 296–301.

MAIER, V. P., and TAPPEL, A. L.: Measurement of enzyme reaction velocities at low temperatures, *Anal. Chem.*, **26**, 564–567, March, 1954.

Physical Changes

CHANDLER, W. H.: How freezing kills plants or plant parts, *Fruit Products J.*, **11**, October, 1932.

JOSLYN, M. A., and MARSH, G. L.: Changes occurring during freezing, storage and thawing of fruits and vegetables, *Univ. Calif. Agr. Expt. Sta. Bull.* 551, May, 1933.

——— and ———: Observations on the effect of rate of freezing on the texture of certain fruits and vegetables, *Fruit Products J.*, **11**, July, 1932.

MACARTHUR, M.: Effect of method of freezing, type of pack and storage on asparagus tissue, *Sci. Agr.*, **28**(4), 166–174, April, 1948.

MARSH, G. L.: Observations on the loss in weight of fruits after thawing and the value of the weight balance in frozen pack foods, *Fruit Products J.*, **11**, July, 1932.

Temperature Change

JOSLYN, M. A., and MARSH, G. L.: Heat transfer in foods, *Refrig. Eng.*, **24**, 214–224, 234, 236, 239, 1932. See also Diehl, Magness, Gross, and Bonney under General above.

Locker Plants and Home Freezers

MANN, L. B.: Refrigerated food lockers, *U.S. Dept. Agr., Farm Credit Admin., Circ.* C-107, May, 1938

MARTIN, W. H., and PRICE, F. E.: The farm freezing plant, *Ore. Agr. Expt. Sta. Bull.* 399, 1941.

MRAK, VERA G.: Home freezing of foods, *Univ. Calif. Agr. Expt. Sta. Circ.* 420, 1953.

OVERHOLSER, E. L., ET AL.: Locker freezing of fruits and vegetables, *Wash. Agr. Expt. Sta. Bull.* 161, 1943.

TAVERNETTI, J. R.: Construction of farm refrigerators and freezers, *Univ. Calif. Agr. Expt. Sta. Circ.* 387, 1948.

TRESSLER, D. K., EVERS, C. F., and EVERS, B. N.: "Into the Freezer and Out," Avi Publishing Co., New York, 1953.

WILKINS, P. C., MANN, L. B., and MINERS, B. D.: Frozen food lockers, *U.S. Dept. Agr., Food Conserv. Serv., Circ.* 17, June, 1956.

Fruit Juices and Concentrates

CRUESS, W. V.: Comparison of frozen and canned tomato juice, *Quick Frozen Foods*, **5**(10), 118, October, 1948.

———, GLAZEWSKI, I. G. A., and SMITH, H. S.: Experiments on frozen citrus juices and syrups, *Fruit Products J.*, **26**(1), 25, 26, September, 1946.

——— and RIVERA, W.: Frozen pack prune concentrate, *Fruit Products J.*, **28**(10), 295, 313, June, 1949.

ECKART, T. G., and CRUESS, W. V.: Freezing storage of pineapple products, *Fruit Products J.*, **10**, August, 1931, pp. 364–366.

KELLY, E. J.: New low-temperature evaporator doubles plant production, *Food Inds.*, **21**, 1386–89, 1949. Concentration of citrus juices for freezing.

LOCKABEY, V. A.: Triple-effect frozen juice concentration, *Western Canner and Packer*, February, 1950.

TRESSLER, D. K., and JOSLYN, M. A.: "Fruit and Vegetable Juice Production," Avi Publishing Co., New York, 1954.

JOURNALS

The Canner and Freezer, Chicago, Ill.

Food Engineering (formerly *Food Industries*), McGraw-Hill Publishing Company, Inc., New York.

Frozen Food Field, New York.

Ice and Refrigeration, Nickerson and Collins Co., Chicago, Ill.

The Locker Operator, Des Moines, Iowa.

Quick Frozen Foods, New York.

Refrigerating Engineering, American Association of Refrigerating Engineers, New York.

Western Canner and Packer, Miller Freeman Publications, San Francisco, Calif.

CHAPTER 26

PLANT SANITATION

That food for human consumption should be produced under conditions of cleanliness and hygienic decency is more or less axiomatic. No consumer would knowingly wish to eat food that has been canned, dried, or otherwise processed in a rat-infested, insect-ridden, filthy, or bacteriologically unclean factory. Clean food cannot be produced in dirty equipment and surroundings.

Cleanliness, or good plant sanitation, often reduces loss from bacterial spoilage, molding, fermentation, insect infestation, and rodent damage or contamination. Incidentally, it will avoid costly conflicts with Federal, state, and local city food regulations and officials. In recent years these agencies have become plant-sanitation-conscious and are becoming increasingly vigilant and active in respect to enforcement of food regulations and legal sanitation requirements in all manner of food establishments, ranging from restaurants and ice-cream parlors to canneries, flour mills, and dried-fruit packing plants. It therefore is imperative that the canner, dried-fruit processor, and other food packers acquaint themselves with the regulations and take steps to maintain their plants as free as is humanly possible of rats, mice, insects, and breeding places of spoilage organisms.

Disposal of plant wastes is a very important part of the sanitation picture. It has been discussed briefly in Chapter 23, Utilization of Waste Fruits and Vegetables and Disposal of Wastes.

The subject of plant sanitation is so large and has so many aspects and ramifications that it cannot be covered fully in this chapter. The reader is referred to the bibliography at the end of the chapter for further study.

Plant Location. As R. E. Sanborn of the California Packing Corporation (1946) has emphasized, three sanitary considerations are involved in selecting a site for a plant. First is an adequate supply of potable water. Food should never be washed with water that is unfit for drinking. Contaminated water may carry infection to the plant's employees or infect canned foods during cooling of the cans or of fruits and vegetables for frozen pack. Garbage or solid-waste disposal is a second consideration, since a large proportion of the raw product becomes waste during preparation for canning, freezing, etc. A third consideration is adequate facilities for disposal

of liquid wastes. In a small town or in the country this may become a very serious problem. Some large cities are reluctant to have liquid wastes from food plants emptied into their already severely taxed sewage systems. In a rural location the canner, freezer, winery, or dehydrater operator may have to install a sewage-treating and disposal system in order to prevent legal proceedings by nearby communities.

Plant Layout. Convenience and accessibility of machinery are desirable in order to permit easy cleaning. There should be streamlined flow of product from receiving platform to warehouse. Floors should be sloped to an ample number of floor drains or gutters. Equipment should be located convenient to floor drains. This requirement is particularly essential for peeling machines, washers, and sorting and trimming tables or belts.

There should be ample space between machines, canning tables, and sorting belts. Adequate lighting at all points in the plant is essential, but is particularly needed at preparation and sorting locations.

RODENTS AND RODENT CONTROL

E. Doyle (1946) estimates that it costs America about $2 a year to feed a rat, merely for the food consumed. There are probably at least as many rats as there are human beings; thus the feed bill for the rat is roughly 325 million dollars worth of food a year, according to Doyle. The rat is also a carrier of filth and spreads its droppings, hair, and urine on foods in bags, boxes, and bins. It is also notorious as a carrier of bubonic plague, typhus, paratyphoid (Salmonella group of intestinal bacteria), and other diseases. For these and other reasons rats should not be tolerated in food plants.

Rats are always much more numerous than the few that one occasionally sees in the plant; there are often 20 hidden rats for each one that is seen. They are nocturnal and seldom seen in daytime. They are omniverous, i.e., they eat anything that has any food value. Hence all sorts of food refuse is food for rats.

Rat Species. Three species of rats commonly infest food establishments, viz., the brown, or so-called "Norwegian," rat, the black rat, and the gray rat (roof rat). The brown rat, much the most prevalent and destructive, is the one that generally lives in basements or elsewhere on or near the floor, as in double walls, piles of boxes or waste lumber, piles of sacks, etc. Brown rats sometimes attack infants and small children and have been known to put cats and small terriers to flight. The other two species are roof rats and will be seen occasionally on or near the rafters and joists supporting the roof. They are recognized by their color, their smaller size, and their tails, which are longer than those of the brown rat.

Cunning of Rats. Rats for many centuries have lived with humans and have acquired much of man's cunning and reasoning ability. They soon

recognize and avoid poisoned baits and traps. The death of one is a warning to the living, a warning that is usually heeded. Hence trappers and rat poisoners must be alert, resourceful, and able to change tactics in order to destroy an appreciable number of the plant's rat population.

Evidence of Infestation. Telltale droppings are the most common evidence of the rat's presence. On bags of salt or sugar one may often detect "dribblings" of dried rat urine by placing the bag under an ultraviolet lamp; the affected area will fluoresce. However, this test must be used with caution, as other substances may give a positive test. Runways, usually near a wall, tracks on sugar bags, etc., gnawings on walls, doors, and floors, burrows, occasional dead rats, nests, rat odors, and live rats are other common indications. By sprinkling flour or talcum powder in suspected runways the rats' trail can often be followed.

Rat hairs in the food product are used by food inspectors as positive evidence of rodent contamination. Methods are available for concentrating the hairs and detecting and identifying them under a microscope. Rats ingest their own hair, which then appears in their droppings. If the droppings enter sirups used in canning, or wine or other food liquid, the hairs can be found and identified as having come from droppings.

Elimination of Harborages. Rats are fond of boxed or partly closed-in places such as unsealed double walls, unsealed double floors, closets, granaries, and like places. As previously mentioned, piles of sacks, old lumber, boxes, stacks of bagged salt or sugar, rubbish dumps, and unsealed basements are all suitable as homes of rats and are much used for the purpose.

Where such rat harborages exist they should be eliminated by removal, by sealing against entrance, or by other means.

Excluding Rats from Plant. Some modern plants can be made ratproof, but great care, ingenuity, and skill in construction are necessary. If doors are left open at night, rats will enter. They may enter through skylights and partly closed windows and have been known to enter via the sewer system by climbing through the drainpipe to a toilet bowl and then diving upward through the water in the trap of the bowl.

Mice. The statements concerning rats also apply to mice. In fact, they are more difficult to exclude.

Rodentproof Storage. Medium-gauge hardware cloth of ¼-in. mesh may be used to build rodentproof enclosures inside the plant for bins of bulk dried fruit, sugar, salt, spices, cured meats, and other supplies or vulnerable finished food products. One-half inch will admit young mice; hence ¼- or ⅛-in. mesh is necessary. Metal containers, such as friction-top 5- or 10-gal. cans and new garbage cans, are suitable for some supplies such as spices. Other devices will occur to the reader.

Trapping. Mice are easily trapped, although in a large plant it is usually not feasible to catch all of them. They are apt to reproduce more rapidly than they are trapped.

Rats are much more wary of traps. Setting of traps in runways near walls will often catch a fair number. They are apt to shy clear of baited traps. Small two-jawed "coon" traps and the familiar wooden-base "snapover" rattrap can both be used. Usually trapping must be supplemented by poisoning, cleanup of harborages, and excluding rodents from the plant.

Poisoning. Poisoning is the more frequent control measure. There are many rat poisons, very few of which are very effective. Naturally, rat poison in a food plant is hazardous and must be used with great care. Doyle (1946) advises that it be left only 24 to 48 hr., then be picked up and safely disposed of. Do not put it in the garbage, as valuable garbage-fed hogs may then be killed. It should never be placed where it may contaminate food or food ingredients.

One man in large plants should be assigned to rat control as his sole duty. In small plants some one dependable employee can be assigned to part-time rodent control.

Red squill, a plant product, has been a favorite rat poison, since it is not poisonous to other animals, including man. Red squill is a powerful emetic, and therefore other animals eliminate it if taken in poisonous doses; but the rat cannot vomit, hence retains the poison and is killed by it if he has eaten sufficient. But very often it merely makes the rat ill, and forever after he will not touch red squill. It is used in the ratio of 1 part of the powder to 9 of bait.

One part of barium carbonate to four of bait is effective but is also dangerous to other animals and humans.

Phosphorus, as zinc phosphide or other toxic compounds of phosphorus, is used as a 2 per cent paste spread on the bait. While it probably will not ignite spontaneously, as some have feared, it is a very powerful slow poison for all animals. The same observations apply to arsenic, used as 1 part to 15 of bait.

Strychnine is a quick-acting and very powerful poison. It is intensely bitter, making it necessary to disguise its presence on the bait. Usually it is mixed for use by dissolving ½ oz. in a pint of boiling water, diluting with a pint of heavy sirup, and coating wheat, oats, or barley with the sirup. It should not be placed in buildings, as it is readily mistaken by children.

Thallium sulfate has been used very successfully on poisoned wheat and barley to eliminate ground squirrels in California pastures and fields. It is very powerful and slow-acting poison. It should be used only by a licensed operator; the same is true of zinc phosphide.

Recently an entirely new rodenticide has come on the market. This is

1080, a complex compound said to be the most toxic substance known. It is used at the rate of 1 to 600 of bait. Because of its extreme toxicity it should be used only by licensed operators.

Antu is another synthetic poison that appears to be specific for the brown rat and not very toxic to humans.

Warfarin, developed by the University of Wisconsin, is now used extensively for the control of rats and mice. It acts slowly and causes death by internal bleeding. A large single dose will not kill; to cause death it must be ingested repeatedly, ordinarily over a period of about 10 days. The great advantage of the product is that rats and mice apparently do not notice by taste or odor its presence in the bait. The poisoned bait must be put out repeatedly over a period of 10 days to 2 weeks in order to maintain a fresh and fairly constant supply. For rats it is recommended that the bait contain about 0.025 per cent of Warfarin and for mice about 0.05 per cent. Health authorities will gladly furnish directions for its use.

Some poisoners use bait boxes with an entrance large enough to admit rats but which excludes larger animals. In these the bait should be of a type that the rat will not remove.

Doyle suggests that the rats be "chummed" the first few evenings by being given unpoisoned bait in order to gain their confidence. Then poisoned bait carrying sufficient poison to kill (not merely sicken) is placed in the previous evenings' feeding places. This procedure may be repeated once or twice, after which poisoning and feeding may be discontinued for a period. Chumming is probably not necessary with Warfarin since its presence in the bait apparently gives no warning to rodents.

Baits. Doyle (1946) lists the following baits: raw meat such as hamburger and sausage, raw or canned fish, bacon, rolled oats, corn meal, bread, canned meat, cooked cereals, other whole or rolled grains, cheese, meat scraps, egg, powdered milk, raw or cooked vegetables, fruits, melon, and many others. Doyle suggests that frequent change of bait is advisable.

Cats and Dogs. As Doyle indicates, cats and terriers are apt to contaminate the food as badly as do the rats. Also, rats soon learn to live with cats and even to "gang up" on them, the cat then becoming the victim.

Viruses and Rat-disease Bacteria. These have been used extensively with the object of initiating a devastating epidemic among the rats, but they have not proved very effective. Also, some may cause serious illness in humans. They are not recommended.

Fumigation. If the building or structure such as a dried-fruit storeroom can be made gastight, it may be sealed and fumigated with methyl bromide, which kills not only insects but also rodents. As it is very dangerous to human beings, it should be used only by a licensed operator. Hydrocyanic acid is effective but is absorbed in dangerous amounts by dried fruits and

some other foods. Usually it is not feasible to fumigate a food-processing plant.

If the rats' burrows can be found, fumigation of these with carbon disulfide, prussic acid, or methyl bromide can be done. Calcium cyanide dust can also be used in burrows.

INSECTS

Insect infestation is a common and very costly cause of loss and spoilage of dry foods such as grains, flour, dried fruits, and dried vegetables. The more common dried-food insects are described, and methods of control are given, in Chapter 20, to which the reader is referred.

Flies. In addition to the dried-food insects of Chapter 20, there must be considered the common housefly and other household insects. The housefly breeds in manure piles, garbage, human excrement, and other refuse. The blowfly, an even more obnoxious insect, breeds in meat refuse and dead animals. The housefly breeds at a tremendous rate; one female deposits 600 to 900 eggs in a lifetime of 2 months. These develop to adults in 6 to 8 days under favorable conditions. They in turn may produce like numbers of eggs.

Screens on windows, doors, skylights, and ventilators will exclude many of the flies. Painting the screens with a 5 per cent DDT solution in kerosene will kill many. Painting of the walls with the same preparation is also effective, except that the dying flies may fall into sirup tanks, cans, etc.

Spraying manure piles and barn walls with DDT, lindane, chlordane, or other residual contact insecticide is very effective at the source. Elimination of such breeding places is highly desirable; therein lies plant sanitation.

Another pestiferous fly in vinegar factories, tomato-products canneries, wineries, and juice factories is the vinegar fly, *Drosophila melanogaster*. The fly is very small and often swarms in veritable clouds in winery fermentation and vinegar-generator rooms. Plant sanitation is essential to its control. Remove all fresh fruit and vegetable waste to a safe distance and dispose of it by drying or feeding or otherwise. Spraying of walls, vinegar generators, wine tanks, pomace piles, etc., with suitable DDT solution is effective, according to Doyle (1946). Control of vinegar flies in and around tomato-products plants is discussed in Chapter 16.

Cockroaches. There are five common species of this universal pest. They are more troublesome in warm, humid localities than in those of low humidity, but they may and do occur in all temperate and tropical climates. Like rats, they are omnivorous. They are very prolific and live for 2 to 3 years. They breed and live in cracks, crevices, under moist boards, etc. If pyrethrum or sodium fluoride is applied to cracks and other likely places, fair

control may be secured. DDT applied as a 20 per cent solution is effective after several days, according to Doyle (1946). Residual, contact insecticides, such as lindane and chlordane, are also probably effective.

Crickets. In cricket season (late summer in California) crickets may invade homes and factories, getting into or on exposed food and becoming a general nuisance. A 3 per cent DDT dust applied to cracks and to floor along walls is very effective. A little of the powder picked up by the insects' legs or body is sufficient to kill.

Ants. In California, Argentine ants are a common pest. They are attracted by sugar, sirups, and many other foods.

Ant pastes containing sodium arsenite or thallium sulfate are commonly used. Kerosene or carbon disulfide applied to nests will destroy the inhabitants. DDT powder (3 to 5 per cent DDT) placed in runways is effective in the author's laboratories.

Wasps and Bees. Late in the summer great numbers of bees and wasps may enter the sirup-preparation room and the canning room. Screening is advisable, but still many may enter. They drop into sirup tanks, siruping machines, and cans and also annoy the workers.

Doyle says that 20 per cent DDT dust can be used on wasp nests and bees' nests in hollow trees, attics, etc. But they come from far and near; hence it is difficult to locate and treat all nests. Also, a nearby commercial apiary would object to poisoning of its beehives. If these insects become very numerous and pestiferous, it may be necessary to screen the sirup room.

MICROORGANISMS

Microorganisms damage and spoil not only canned foods but also many other food products. Dried fruits and vegetables may mold or ferment; peas en route to the cannery or freezer may sour or partially putrefy; fruit juices to be canned, bottled, or frozen may partially spoil between extraction and packaging; milk or juices to be frozen may become contaminated with the *Bacillus coli* group of organisms, evidence of fecal contamination, or possible typhoid contamination. Thermophilic bacteria may become established in hot-brine tanks, pipes, pumps, blanchers, belts, etc., and contaminate the product so badly before canning that excessive spoilage ensues even after heavy processing by heat. Hence plant sanitation includes control of various microorganisms. This subject has been considered to some degree in Chapter 11, Spoiling of Canned Foods, but further discussion will be given here.

General Plant Cleanliness. A clean plant greatly reduces contamination of the product with spoilage organisms, thus reducing spoilage; prevents contamination of the food with debris left on the machinery and equipment;

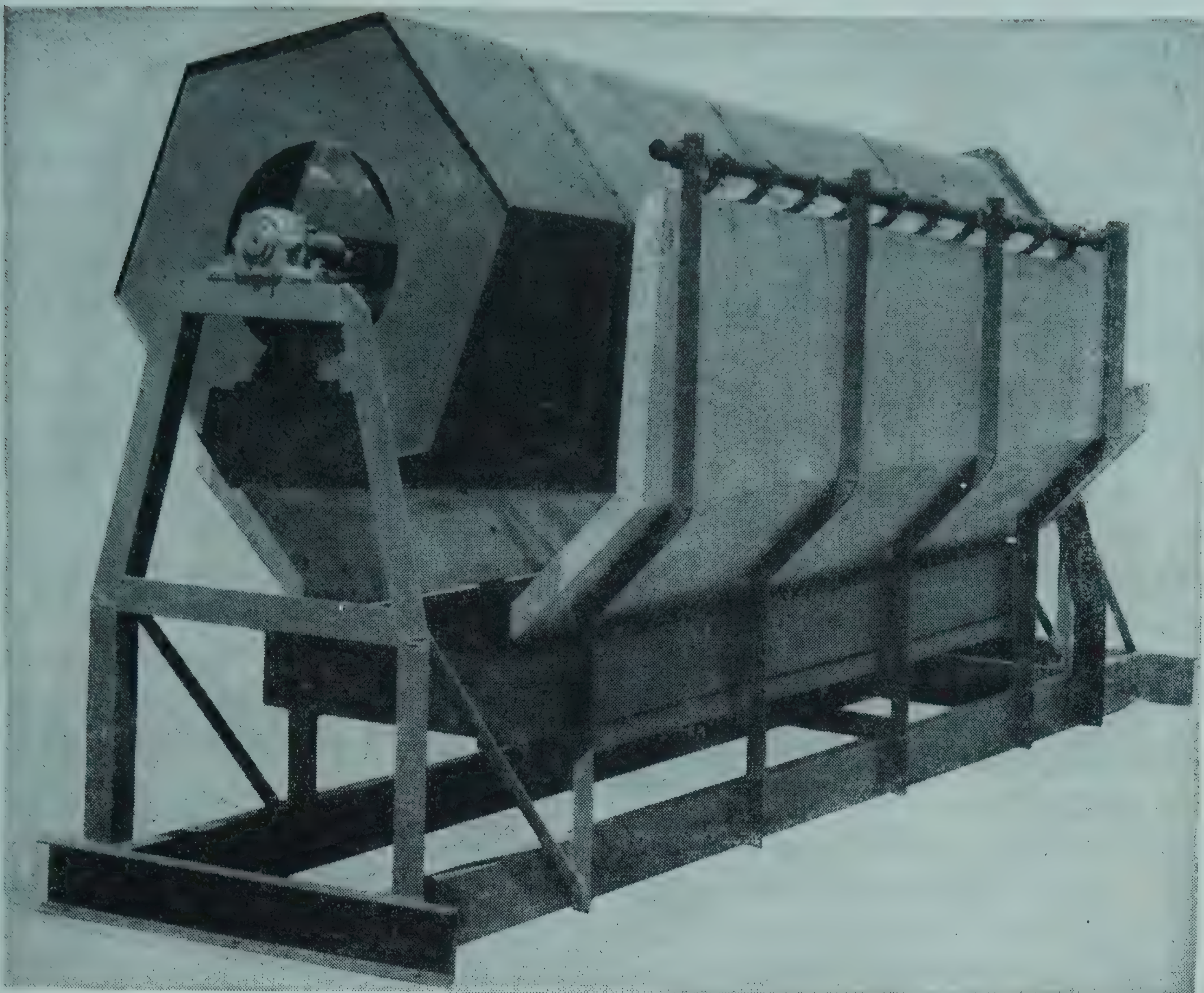


FIG. 124. Revolving screen to remove coarse solids from waste liquids. (*Atlas Pacific Engineering Co.*, Oakland, Calif.)

raises employee morale; builds consumer confidence; and greatly reduces the possibility of food seizure or condemnation by food officials.

Equipment should be so placed that it and the adjacent floor can be easily cleaned. Also, it should be of sanitary design and construction, i.e., easily dismantled for convenience and thoroughness of cleaning.

Cleanup and Cleanup Crews. Cleanups should be frequent and thorough; in some plants once a day will suffice, in others two to four times a day may be necessary.

There should be an organized crew for this job, although during part of the day they may have other duties. In this case they should be paid an incentive bonus. The men should be trained to locate dirt and debris and to remove it effectively, with minimum interference with production.

As there is a wide variety of equipment, cleaning methods vary. Some machines are in cramped quarters, making effective cleaning difficult or even impossible. Various detergents are recommended by manufacturers, but as the National Canners Association points out, little is known about their effectiveness. Plenty of hot water under strong pressure from a 1-in. hose will dislodge most debris and wash it to the drain. Solid particles

should be screened out at the drain and not allowed to enter the sewer, as they will cause trouble in the city's or plant's sewage system.

Greasy coatings on sealing machines, as in fish canneries, may require washing with hot soda-ash solution or strong soap. Oil on floors is a hazard to workmen and can be removed by applying powdered T.S.P. (Trisodium-phosphate) and using a scrubbing brush.

Cleaning Belts. Sorting and canning belts usually develop crops of bacteria, yeast, or mold, or all three, unless they are frequently cleaned and sterilized. In some vegetable-dehydration plants during the Second World War, dilute chlorine solution was applied continuously to the empty belt as it traveled underneath the table. Vaughn (1946) found that the customary twice-a-day steaming of the belt from a steam hose merely spread the organisms and that a bacterial plate count made after such steaming was usually higher than before steaming. This increase in count was caused by breaking up of bacterial clumps and forcing bacteria out of the pores of the belt. He recommends treating with dilute chlorine solution, preferably continuously, as it is not practicable to heat belts sufficiently to destroy many of the microorganisms. Scrubbing with stiff brushes may be required if the product imparts a slimy coating to the belt. Its condition should be checked frequently by bacterial-plate counts made by swabbing and plating from a measured area of the belt.

Metal equipment, however, can be heated sufficiently by steam blast from a steam hose to kill vegetative forms and is quite effective on double-seaming machines, sirupers, and other like equipment, if applied for a sufficient time for the metal to reach killing temperature.

Importance of Form of Equipment. The National Canners Association recommends rounded corners, openings to permit cleaning, easy dismantling, and metal in preference to wood. The Association also advises that dead ends and pockets be avoided in pipelines and other conduits. Splash pans and drip pans should be removable for easy cleaning.

Valves should be simple in form and easily cleaned. Pumps should be easily dismantled. Flumes should not be rectangular but should be rounded in contour and easily cleaned. Hoppers should be smooth and free of crevices that will retain juice or debris. Preheaters, pasteurizers, and heat interchangers must be easily and quickly opened for frequent cleaning.

Blanchers are sometimes a source of contamination because they are so constructed that cleaning is next to impossible; and because the temperature in some locations is not high enough to prevent the growth of thermophiles. Cyclones, juicers, and finishers require frequent cleaning, hence must be readily opened.

Recent research by the National Canners Association has resulted in the design of a blancher that can be easily cleaned and sterilized and in which there are no locations of low enough temperature for growth of

thermophiles (see National Canners Association, Research Laboratories Annual Report, 1955; also Figure 13).

Sterilizing Fresh Citrus Fruit. In the preparation of citrus juices for freezing it is essential to keep the bacterial count of the juice low because boards of health make bacterial counts to detect possible contamination with colon organisms. Hence it is customary to thoroughly scrub the fruit mechanically in sprays of water and to immerse it in a disinfectant solution such as that of a quarternary amine, said to be very effective. Chlorinated water is also used. Because of the large amount of organic matter present in the bath, the chlorine is soon "used up" and becomes ineffective. This problem requires much study, as the producers are at present working in the dark.

Sterilizing of Equipment. Sterilization of sorting belts with dilute chlorine has been mentioned. Press cloths and filter cloths are usually sterilized in boiling water.

Pumps, pipelines, fillers, hoses, cappers, and some other equipment may often require sterilization by disinfectant such as dilute chlorine solution or hot T.S.P. Sulfur dioxide gas or solution is a common disinfectant for tanks, barrels, and hoses in the winery and vinegar plant. Chlorine and sulfur dioxide may damage certain metallic equipment such as pear peelers. Lug boxes should be washed and sterilized regularly. Painting the inside of the boxes with Cellu-san or other effective product is a good mold-preventive measure (Figure 125).

General Notes on Cleaning. The National Canners Association and Association of Food Sanitarians, 1952, recommend that all equipment be thoroughly cleaned at least once a day. Those in which waste and debris may collect, e.g., fillers, closing machines, and pear peelers, peach pitters, graders, and washers, should be cleaned more often. Other suggestions made are the following: Do not allow food particles to dry on the machinery; clean promptly. Warm water at 120 to 140°F. is often more effective than steam or very hot water as the latter may bake the food onto the metal. Start at the top of the machine and wash down. Feel surfaces of belts, washers, etc.; if they feel slick there is probably a heavy growth of micro-organisms. Heavy brushing or use of hot detergents may be needed in such cases. Brushes should be made of materials that will not soften or dissolve in caustic solutions and should be so designed that all corners of the equipment can be reached. Live steam does not do a satisfactory cleaning job and does not sterilize; however, it warms metal equipment so that it will dry without rusting.

A satisfactory detergent must wet the surface readily so that water will flow freely over all the surface, must carry the substance to be removed in suspension, and must be easily rinsable from the equipment without leaving a deposit. One good caustic detergent is a mixture of sodium hydroxide and

sodium ortho- or metasilicate; it is less caustic than pure hydroxide solution and is a good wetter. Tri-sodium-phosphate (T.S.P.), a common and effective detergent used in washing floors and equipment, is a good emulsifier for oils, prevents calcium deposits in hard waters, is a good water softener, and is not excessively caustic.

Surface-acting agents of cationic nature such as the quarternary ammonium compounds (Roccal, Emulsol, etc.) act in acid solutions only and thus are inactivated by soaps; they act as detergents and germicides. The anionics (Dreft, Vel, Drene, etc.) work in alkaline solutions and are effective in many cases. Soap belongs to this class also. There are also nonionic detergents. Be careful that your detergent does not impart an off flavor to your product. See "Conference on Food Plant Sanitation," National Canners Association, Western Research Laboratories, 1946, and the book "Sanitation for the Food Industries," both listed in references at the end of this chapter.

Chlorination. For many years the domestic water supply of most American communities has been rendered safe for drinking and other uses by carefully controlled chlorination. Its use in canneries, freezing plants, and other fruit and vegetable processing establishments has been adopted more recently; the dairy-products industry has employed it for a considerable time. Because of the increasing interest of food and drug agencies in sanitation in food-processing industries and the rapidly increasing cost of labor, any innovation that will both cut labor costs and render the finished product more acceptable in the eyes of the law is of great importance to the food processor. Chlorination is one such practice.

Chlorination of the water supply of a plant beyond the break point is termed "in-plant chlorination." Break point refers to the residual chlorine content of the treated water and may be explained as follows: Water contains substances, for the most part organic, that react with or combine with chlorine. When a small amount of chlorine, say, 0.5 to 1.0 p.p.m., is added, much of it is used up in the above manner, and as a consequence the residual (unused) chlorine level increases but little. As progressively more chlorine is added, the residual reaches a maximum, and then actually declines to a minimum as more chlorine is added. Beyond this minimum the residual chlorine content again rises as the addition of chlorine is continued. The minimum point at which this change occurs is known as the break point. Beyond it most of the chlorine that is added appears as residual. During that portion of the curve of "chlorine added" versus "residual chlorine," in which the residual is decreasing with additions of chlorine, it is being consumed in complete oxidation of various organic substances in the water, and after this has been accomplished the residual then rises more or less in direct proportion to the amount of chlorine added.

Somers (1951) in extensive studies in four canneries in which the free-

residual-chlorine levels ranged from 2 to 10 p.p.m., found that lower populations of mesophilic microorganisms prevailed in and on equipment thus treated; that it prevented the formation of bacterial slime on equipment, on floors, in flumes, around closing machines, gutters, belts, etc., and eliminated odors. Chlorine used at a residual of 4 to 5 p.p.m. had no deleterious effect on flavor of 26 canned fruit and vegetable products, provided that the water used in making up of sirups and brines added to the cans of product was not chlorinated. Harris (1947) states that a residual of 0.5 to 1 p.p.m. of free chlorine in the general water supply may often be adequate, but this is a point that must be determined for each plant and its water supply. Some waters may require a heavier dosage. Somers found no increased corrosion attributable to chlorination of the water supply when a residual of 5 p.p.m. was maintained. A level of 20 p.p.m. in cleanup water also did not cause corrosion. The products being canned were peas, corn, cherries, apricots, peaches, pears, and fruit cocktail. Bacterial build-up and slime formation were prevented in conveyers, bucket elevators, and other equipment in contact with the raw or blanched material. At 4 to 5 p.p.m. there was no detectable effect on the ascorbic acid content or the pH value of the products studied. A concentration of 50 p.p.m. caused an off flavor in some products and the darkening of cut, light-colored fruits such as pears and apples; but this level is at least ten times that generally recommended. Plant personnel considered in-plant chlorination to be a very valuable aid to plant sanitation and very effective in reducing the time and labor required in clean-up operations.

Marginal chlorination at 0.05 to 0.10 p.p.m. used to sterilize drinking water may cause off odors and flavors due to the formation of chlorophenols, etc. Break-point chlorination eliminates or prevents such odors and flavors by completely oxidizing dissolved organics.

Chlorine gas is made by electrolysis of sodium chloride solution and is then collected and compressed to a liquid in steel cylinders. For industrial use these range in size from a capacity of 100 to 150 lb. to 1 ton or to tank-car size. Chlorinators that add automatically to water the desired amount of chlorine are made by a number of suppliers. These add the chlorine gas to a small amount of water and inject this solution continuously into the water supply. It may be added at a constant rate or at a rate that varies with the rate of water flow, the latter type being preferred for use in a food-processing establishment. Full directions for installation of the chlorinator and its use are furnished by the supplier of the equipment. Only a well-designed, thoroughly proved type of chlorinator should be used. It should be in the charge of a man properly trained in its use and upkeep. Suppliers of chlorinating equipment or of liquefied chlorine are glad to instruct one or more members of the plant's personnel in this task. The equipment should be inspected frequently to see that it is operating prop-

erly, and frequent samples of the chlorinated water should be taken and analyzed for residual chlorine content. Simple equipment and methods of chlorine determination are furnished by chlorine-equipment-supply companies. Prominent signs should be posted near the chlorinator giving instructions for its operation and action to be taken in case of leaks or breakdown. Chlorine gas is very toxic and obnoxious; consequently a gas mask should be placed outside the chlorinating room rather than in the room. Gas leaks can be detected easily by use of a bottle of ammonia water; a white cloud will appear above the open bottle if much free chlorine is present in the air of the chlorinating room or at any other point tested.

For cleanup and certain other special purposes requiring a high concentration of chlorine, hypochlorite solutions are sometimes used. Either the calcium or the sodium salt may be used. Calcium hypochlorite solutions give white deposits or sediments and should be allowed to settle before use. As hypochlorites are unstable, they should be made up daily. For general use, including break-point chlorination, hypochlorites are in some respects more suitable for the small cannery or small freezer than is chlorine gas. It is less dangerous to handle; it is convenient; it is less corrosive on equipment; and the equipment is less costly than that required for chlorine gas. It is, however, more costly to buy, as pointed out by Harris. He stated (1947) that under conditions then prevailing it would cost about $12.80 to chlorinate 1 million gal. of water at the rate of 2.5 p.p.m. added, or about 1 p.p.m. residual for most waters, if hypochlorite of 65 per cent available chlorine content and a cost of 40 cents per pound for the dry salt were used; and only $1.55 if liquefied chlorine gas were used, costing 7½ cents per pound; or $0.42 if the cost (as by tank carlots) were 2 cents per pound. However, a heavier investment in chlorinating equipment is required for the liquefied gas and would tend to counterbalance in some degree the greater cost of the hypochlorite. Since hypochlorite solutions are unstable, they should be made up daily or as needed. Nonmetallic containers and corrosion-resistant pumps, pipelines, and other equipment used in handling the solution are desirable; although hypochlorite solutions, because they are alkaline, are less corrosive on most equipment than are those made with the gas.

Mercer found that water may be reused as many as four times in successive operations in a pea cannery if the water is chlorinated to 0.5 p.p.m. residual before each reuse. Harris considers 1 to 2 p.p.m. residual chlorine as adequate in water used in the cooling of heat-processed cans of food, and under some conditions it may be even lower. Bacterial counts should be made frequently on the cooling water; Harris recommends that it be kept below 500 living cells per cubic centimeter. If the count begins to increase, it may be advisable to chlorinate the water to 5 p.p.m. residual as it comes from the cooling tower until conditions return to normal. Cameron and

Williams found in one case a count of 100,000 cells per cubic centimeter before chlorinating the cooling water and less than 25 per cubic centimeter when chlorinated to 1 p.p.m. residual. Bacterial samples should be taken frequently from conveyers, flumes, belts, and other equipment being treated with chlorinated water, and counts made of viable cells to check upon the effectiveness of the sanitation program.

While break-point chlorination of the water supply and use of chlorine and hypochlorites in other ways in the plant are extremely useful aids to plant sanitation, they are not cure-alls and should be considered as supplementary to good housekeeping and satisfactory general plant sanitation.

Other Considerations. Neat uniforms encourage cleanliness and care in preparation and processing. Caps or other head covering are essential and advisable to prevent hairs getting into the finished product. Workmen with skin disorders should not handle the finished product, particularly in plants such as freezers, in which it is not sterilized in hermetic containers.

Adequate first-aid supplies are a must; in addition most plants maintain a well-equipped first-aid room, and in large plants a full-time nurse may be on duty.

Most canneries and freezers have a restaurant or cafeteria in operation throughout the working day to serve meals at specified times and coffee and snacks between meal hours.

Toilets and urinals must be adequate and located at proper points. Washing of the hands after use of toilet facilities should be mandatory. Toilets should be located at a reasonable distance from the packaging lines. Safe drinking water and drinking fountains with proper guards to prevent contact of the mouth or nose with the water outlet should be provided.

While detergents are desirable in some cleanup operations or in the washing of certain raw products, excessive use may cause troublesome foaming in the sewage-disposal system of the city or that of the plant. Insect and rodent foods such as waste peels, etc., and harborages such as piles of old sacks, broken cartons, discarded machinery, etc., should be eliminated.

Dried fruit, if held for several months, may require cold storage or storage in a tight room in which it can be fumigated continuously or frequently. If floors, walls, or other locations are sprayed with an insecticide to control vinegar flies, cockroaches, or other insects, a material should be used that does not impart a disagreeable flavor or odor to food products. Lindane is objectionable from that standpoint, whereas DDT is satisfactory.

While public-health agencies consider members of the *Escherichia coli* group of bacteria as the most reliable indicators of filth contamination of a water supply or food product, the cannery or other food processor is more apt to use the total bacterial count or that of certain spoilage organisms, e.g., thermophile spores in a corn cannery, as a criterion. However, for

frozen foods, the *E. coli* group count is customary as an indication of sanitary condition of the product, especially for those products, such as frozen juices and concentrates, which are to be served without heat-treatment. Samples taken by sterile swab from belts, conveyers, fillers, etc., and plated for bacterial counts are very useful in determining the effectiveness of the

FIG. 125. *Right:* Untreated lug box. *Left:* Lug box treated with Cellu-san. Note heavy growth of mold in untreated box. (*Cellu-san Division, Darworth, Inc., Simsbury, Conn.*)

plants sanitation program. Such counts are routine and customary in large plants that have a well-equipped laboratory and bacteriologist.

Wells should be so located and of such depth that contamination by sewage seepage or other undesirable source is precluded. Back syphoning of sewage in the plant should be prevented by proper layout of water lines and sewage-carrying lines. The roof must be rainproof so that water may not leak through into the products on the floor below. The roof should be rodentproofed at junction with the walls. For the same reason sky lights and windows that are to be left open occasionally should be screened. Walls should be painted and readily cleaned.

Dead ends and other debris collectors in pipelines, flumes, drains, and other conveyers of liquids should be avoided or if present, eliminated. Concrete floors should be used throughout the preparation and processing

departments. Some locations may require surfacing of the concrete with an impervious, tough coating; others, as around a jelly-making or juice-pressing station, may require a heavy coating of asphalt or other material to reduce corrosion of the concrete; it must be understood, however, that asphalt softens with steam or hot water and is not very durable under heavy traffic. A floor slope of ⅛ to ¼ in. per ft. usually permits rapid runoff of wash water and rapid drying after cleanup. If much steeper than this, runoff is too rapid; if much less, the floors will remain wet too long.

Lighting has been covered in Chapters 4 and 7. It must be adequate for the work being done. The Association of Industrial Sanitarians and National Canners Association, 1952, recommend at least 20 foot-candles of light for such operations as filling of cans, ordinary sorting, processing, sealing, siruping, cutting, pitting, and similar operations; and up to 50 foot-candles for critical laboratory examination of canned products or very critical inspection in the plant. They and other authorities on lighting in food plants advise that every food-processing plant have and frequently use a reliable light meter.

Good ventilation, which often means forced ventilation by fan, is advisable in processing rooms and at other points where steam may accumulate in the atmosphere. If ventilation is inadequate, moisture is apt to condense on overhead pipelines, ceiling, etc., and drip into cans of food, etc., and working conditions may become intolerable. Fermentable and putrescible wastes should not be allowed to collect in drains, in corners on the floor, and elsewhere, causing undesirable odors and furnishing food for insects and rodents. Some key person in each department should be designated and held responsible for maintaining his or her unit in good sanitary condition. Large canning organizations in California that operate a number of plants now employ well-trained sanitarians to supervise the sanitation programs in the various canneries and to instruct personnel in this subject.

For further discussion of sanitation in food-processing plants, see one or more of the references listed at the end of this chapter, such as "Sanitation for the Food Preservation Industries" and "Food Plant Sanitation," both recent books on plant sanitation prepared by specialists in the field.

Waste Disposal. This has been covered in Chapters 10 and 23. An excellent review of the subject by Rudolfs and Heukelekian has appeared in *Food Engineering*, 1954.

REFERENCES

Plant Sanitation

"A.B.C. Plant Operation Manual," American Bottlers of Carbonated Beverages, Washington, D.C., 1940.

American Water Works Association: "Standard Specifications for Deep Wells," New York, 1946.

ANDERSON, S. M., ET AL.: Recommendations for operation, modification and construction of drum-type blanchers, *Natl. Canners Assoc. Inform. Letter*, Mar. 19, 1955.

Association of Food Industry Sanitarians, in cooperation with the National Canners Association: "Sanitation for the Food-Preservation Industries," McGraw-Hill Book Company, Inc., New York, 1952.

California State Board of Health: "The Use of DDT in Food Establishments," State Department of Public Health, San Francisco, 1946. See also Dried Fruit Association publication on same topic.

California Dried Fruit Association: Rodent control, San Francisco, July, 1946. A mimeographed circular.

CAMERON, E. J.: Advantages and disadvantages of chlorination of cooling water, *Canner*, **88**, 68, Feb. 24, 1939.

Cleaning in the food industry, Oakite Products Co., New York, 1949.

DuPont Company memoranda concerning ANTU (a new rodenticide), E. I. du Pont de Nemours and Company, Wilmington, Del.

Effect of detergents on sewage and water treatment, *Chem. Ind. News*, **31**(11), 1072–1078, Mar. 16, 1953.

ELDRIDGE, E. F.: "Industrial Waste Treatment Practice," McGraw-Hill Book Company, Inc., New York, 1942.

GRIFFIN, A. E.: Break point chlorination practices, Wallace and Tiernan Co., Inc., *Tech. Bull.* 213, Belleville, N.J., 1946.

HARDENBERGH, W. A., and WEINSTEIN, J. J.: Rat control in New York City, *Modern Sanitation*, **3**(3), 12–16, March, 1951.

HARRIS, J. J.: Chlorination in the food plant, *Continental Can Co., Research Dept., Bull.* 13, 1947.

HAYNES, R., and MUNDT, O.: Chlorine sprays improve processed green beans, *Food Inds.*, **20**, 977–981, 1108, 1948.

HOLSENDORF, R.: The rat and rat proof construction, *U.S. Public Health Serv. Suppl.* 131, 1937.

JOURNALS

Food Engineering: "Food Plant Sanitation and Maintenance," 2d ed., McGraw-Hill Publishing Company, Inc., New York, 1954. A compilation of several papers.

Modern Sanitation, a monthly journal, published by Powell Magazines, Inc., Lancaster, Pa.

KALMBACK, E. R.: "Ten-eighty: a War-produced Rodenticide," U.S. Public Health Service, Atlanta, Ga., 1945.

LAMB, F. C.: Lighting in canneries, *Canning Trade*, May 10 and May 17, 1954.

LINSLEY, E. G., and MICHELBACHER, A. E.: Insects affecting stored food products, *Univ. Calif. Agr. Expt. Sta. Bull.* 676, 1944.

MALLIS, A.: "Handbook of Pest Control," McNair-Dorland Co., New York, 1945.

MCCULLOCH, E. C.: "Disinfection and Sterilization," Lea & Febiger, Philadelphia, 1945.

MERCER, W. A.: Cannery waste disposal and its problems, *Canning Trade*, Apr. 25 and May 2, 1955.

——— and SOMERS, I. I.: Chlorine in food plant sanitation, chap. 3, pp. 120–171, in E. M. Mrak and G. F. Stewart (eds.), "Advances in Food Research," vol. 7, Academic Press, Inc., New York, 1957.

——— and YORK, G. K.: Water re-use in pea canneries, *Canning Trade*, Mar. 9, 1953.

MICHELBACHER, A. E., BACON, O. G., and MIDDLEKAUFF, W. W.: Vinegar fly in tomato fields [control measures], *Univ. Calif., Calif. Agr.*, June, 1953, pp. 9–11.

MRAK, E. M.: Teaching sanitation in connection with food technology curricula, *Food Technol.*, **5**(2), 4143, 1951.

ORR, E. T.: Vinegar fly control, *Canner*, Feb. 14, 1953, pp. 22–24.

PARKER, M.: "Food Plant Sanitation," McGraw-Hill Book Company, Inc., New York, 1948.

RUDOLFS, W. and HEUKELEKIAN, H.: Sure methods of disposing of food wastes, "Food Plant Sanitation and Maintenance," 2d ed., *Food Engineering*, McGraw-Hill Publishing Company, Inc., New York, 1954, pp. 1–13.

RYAN, W. J.: "Water Treatment and Purification," McGraw-Hill Book Company, Inc., New York, 1946.

SAMPSON, W. W.: Selected pest control formulae of interest to sanitarians, *Sanitarian*, January–February, 1944.

———: Annotated outline of the principles of control of rodents affecting man, *Sanitarian*, March–October, 1943.

SANBORN, N. H.: Canning plant sanitation: do's and don'ts, *Natl. Canners Assoc., Conv. Issue, Inform. Letter* 1219, Jan. 26, 1949.

——— ET AL.: Methods of treating cannery waste, *Natl. Canners Assoc., Research Lab., Bull.* 28-L, 1939. See also *Bull.* 29-L, 1945, on same subject.

SCARLETT, W. J., and MARTIN, R. B.: Chlorination in frozen food processing, *Canner*, **106**, 13, Mar. 27, 1948.

SNYDER, C. W.: A survey of urban rat control in the U.S.A., *Modern Sanitation*, November, 1949.

SOMERS, I. I.: Studies on in-plant chlorination, *Food Technol.*, **5**(2), February, 1951.

———: How to select detergents for food plant cleaning, *Food Inds.*, **21**, 295, 296, 429, 430, 1949.

———: How to establish a plant cleaning program, *Food Inds.*, **20**, 8–12, 166–204, 1948.

Treatments for concrete floors, *Portland Cement Assoc. Circ.* ST56, San Francisco, 1946.

VAUGHN, R. H., and STADTMAN, T. C.: Sanitation in the processing plant and its relation to quality of the finished products, *Food Freezing*, **1**(9), 334–336, July, 1946. See also *Quick Frozen Foods*, **9**(2), 76–78, 114, September, 1946; and *Am. J. Public Health*, **35**, 1292, 1945.

———, WINTER, F., and SMITH, E. F.: Continuous sanitation of equipment in the dried fruit industry, *Food Technol.*, **2**(4), 292–296, 1948.

Wallace and Tiernan Co., Inc.: Automatic visible vacuum chlorinator, *Pub.* TP-54-C, Newark, N.J., 1954.

WALSH, J. S.: Better lighting, better work, *Food Inds.*, **18**, 1548, 1550, 1676–1678, 1705–1707, 1830, 1946.

WESTON, R. F.: Industrial water pollution abatement, *Chem. Ind. News*, **31**(2), 134–138, Jan. 12, 1953.

INDEX

Please return this publication on or before the last due date stam
Incurring overdue charges.

To be issued from: ——

DUE DATE	RETURNED ON	DUE DATE
28/6/99	28/6/99	2-4-01
18/7/99	2/7/99	
29/12/99	23/12/99	23.04.01
7/2/2000	15/2	14/5/01
23/9/2K	27-9-2K	31/5/01
		15/6/01
21/11/2K	26/11	2/7/01
10.12.2K	1/12	24.07.01
25-12-2K	27/12/2K	
10/1/2001	10/1/2001	7/8/01
24/1/2001	31/1/2001	23-08-01
14/2/2001	14/2/2001	3.9.01
28/2/2001	2/3/2001	21/9/01
16/3/2001	19/3	7.10.2001
5/11/01	12/11/01	20/10/2001
26/11/01	27/4	